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Problem Water Reference Manual

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WARNING! Problem water treatment occasionally requires the use of chemicals, some of which are hazardous or toxic. To the extent possible, chemical usage should be minimized or avoided, particularly in residential applications.

- **Culligan dealers are advised to encourage customers to have their systems professionally maintained, including the handling and replenishment of all chemicals, through a service contract with the local Culligan dealer.**
- **Where chemical usage is necessary and where consumers elect to store, handle and/or use water treatment chemicals themselves, Culligan dealers are advised to strongly caution consumers about potential hazards and to furnish Material Safety Data Sheets (MSDS) on any chemicals they provide.**
- **When using chemicals, always follow the manufacture recommendation for the use of appropriate personal protective equipment as noted in the MSDS for that chemical**

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Chapter 1

Chapter 1

Introduction To Problem Water

Definition of Problem Water

Since "problem water" is the subject of this manual, the best way to start is to define what it is. In the past, problem water was loosely defined as, "water requiring a treatment more complex than simple softening." Consider the following two definitions:

1. Problem water is water with one or more of the following symptoms:
   - looks bad
   - smells bad
   - tastes bad
   - causes staining/spotting
   - causes corrosion
   - causes personal appearance problems
2. Problem water is water that contains contaminants that do not meet the standards for a particular application.

The first definition often is the one used by the potential customer, who calls you and reports problems like a yellow color, a rotten egg odor, a salty taste, white spotting, or even green hair.

The second definition is the one often used by water treatment professionals. Although the standards may include contaminants known to cause the problems observed by the potential customer, they might also include contaminants causing problems that are not immediately obvious. Perhaps the most common of these "hidden" contaminants is nitrate. It does not cause a look/smell/taste problem, but it may cause health problems for infants, elderly, and immune-compromised individuals.

Which definition should you use? BOTH!

Talk to the customer regarding the problems he or she has identified. Add this information to your own observations. If you do not talk to the customer, you might install equipment that will solve a problem that you identified, but not a problem that the customer identified.

The most common water standards used in the problem water market are the U.S. EPA National Drinking Water Standards (see Appendix). However, there may be other standards more appropriate to a particular application, such as state drinking water standards, beverage water standards, or agriculture water standards. Be certain you know the standards that are appropriate for the application. In some cases, the customer must provide these standards.

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Introduction To Problem Water

The Problem Water Market

There are four primary sources of water used in most homes and commercial applications. Each source has commonly occurring contaminants.

- **Private well** sources often contain iron and/or hydrogen sulfide.
- **Municipal well** sources often contain free chlorine and may cause corrosion.
- **Private surface water** sources often contain microorganisms and sediment, and may cause corrosion.
- **Municipal surface water** sources often contain free chlorine, chloramines, and fine particles, and may cause corrosion.

Private well supplies traditionally are considered the primary problem water market, but all the sources have market potential if the proper approach is used.

Problem Water Is Different

Some salespeople are reluctant to enter the problem water market because of problems encountered in previous applications. Some caution is good, since many problems have been caused by rushing to conclusions regarding the type of problem, its cause, and the water treatment required. Problem water applications are not the same as "simple softener" applications:

- The customer realizes there is a problem with the water. In a sense, water treatment equipment already has been sold. The questions are what treatment will be sold and who will sell it.

- Technical skills are as important, and often more important, than sales skills. Even those customers with no knowledge of water treatment often can tell when a sales representative is not comfortable answering questions about their problem water.

- The possibility of misapplication is greater. Often there are many potential causes of a particular problem. Each cause may require a different kind of water treatment, so it is extremely important to try to find out what is causing the problem.

- The customer is more demanding. For simple softening applications, there are many cases where the customer did not report a problem even though the softener had not been working for years. It is not likely that a customer will ignore iron stains, rotten-egg odor, etc., for very long.

- Although the risks are greater, the reward of being recognized as a Problem Water Expert more than compensates. Most problem water markets are rural or small-municipal, and word-of-mouth can be very important. Success in the problem water market can lead to increased sales in other markets.

This manual is intended to provide technical expertise in problem water applications so that you will make the sale, avoid mis-applications, and enhance your reputation as an expert in problem water markets.

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Approaching Problem Water

Go back and read the two definitions of problem water. Each definition leads to a different approach. The first can be termed the "IDEA" approach:

Step 1. **I**dentify the problem(s).
Talk to the customer! Look at, smell, and taste the water. Examine fixtures for corrosion or staining.

Step 2. **D**evelop a theory regarding the cause of a problem.
For example, blue-green stains might be caused by copper corrosion.

Step 3. **E**xamine the water to determine if the theory is valid.
For example, test for copper before and after flushing the piping.

Step 4. **A**pply equipment if the theory is valid.
If not, develop a new theory.

Since the IDEA approach is the one most commonly used in the field, this manual is organized in the same way: problem, cause, testing, and equipment.

The second approach can be termed the "Water Analysis" approach. Obtain a complete water analysis of the customer's water. In addition to showing contaminants causing known problems, a complete analysis may reveal problems that are not immediately apparent. The most common example is nitrate. Other examples include silica, aluminum, and sulfate.

As with the two definitions, use BOTH approaches. Not only will you maximize the sales potential, you also will be more likely to have a satisfied customer.

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Chapter 2

Chapter 2

Problems and Causes

Review the following quick reference guide and determine which problem matches the problem defined by you and/or your potential customer. Note the potential cause(s) and then refer to the Chapter 3, Causes, and Chapter 4, Testing. NOTE: For contaminants not listed below but listed on the U.S. EPA drinking water standard list, look for the particular contaminant in Chapter 3.

PROBLEM	POTENTIAL CAUSE
Looks Bad	
Turbidity	
White	Suspended Solids Dissolved gasses Microorganisms Aluminum
Brown	Iron (colloidal)
Black	Metallic sulfides Manganese Microorganisms
Color	
Yellow	Iron (colloidal) Tannins
Black	Metallic sulfides Manganese
Blue	Copper
Bubbles	Detergent Dissolved gases
Smells Bad	
Chlorine	Free chlorine Chloramines
Rotten egg	Hydrogen sulfide
Petroleum/gasoline	Petroleum/gasoline
Sewage	Microorganisms
Tastes Bad	
Salty	Chloride
Bitter	Sulfate
Effervescent	Bicarbonate
Metallic	Copper Iron Zinc
Soapy	Detergent

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Problems and Causes

Causes Staining/Deposits

White	Hardness Silica Total Dissolved Solids
Red / Orange Blue	Iron Copper
Black	Metallic sulfide Manganese
Slime	Microorganisms

Causes Corrosion

Copper	Dissolved oxygen Carbon dioxide Chloride Sulfate
Iron	Dissolved oxygen Carbon dioxide Chloride Sulfate
Glassware	Dishwasher detergent

Personal Appearance

Green hair	Copper
Mottled teeth	Fluoride
Dry skin	High pH (Alkalinity)

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Chapter 3

Causes of Water Problems

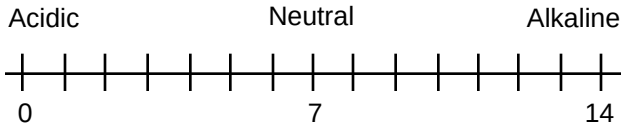
Acidity and Alkalinity

Chemistry: Acidity is related to the amount of hydrogen ions (H^+) in water. The higher the level of hydrogen ions, the higher is the level of acidity.

Alkalinity is related to acidity since it is defined as the ability to neutralize acid. It consists of bicarbonate (HCO_3^{-1}), carbonate (CO_3^{-2}), and hydroxide ions (OH^{-1}).

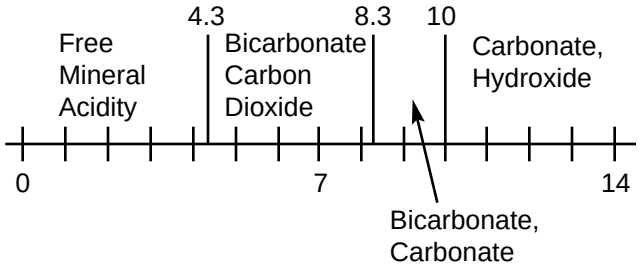
Traditionally, pH has been used to determine relative acidity or alkalinity. A pH of 7 is considered neutral, a pH below 7 is considered acidic, and a pH above 7 is considered alkaline. However, these guidelines apply primarily to pure water.

Theoretical pH Scale



Natural water supplies usually contain carbon dioxide, which combines with water to form carbonic acid. Unlike strong acids (hydrochloric, sulfuric, nitric), this weak acid holds on to most of its hydrogen ions and acts like a molecular acid storage tank. Therefore, pH, acidity, and alkalinity in natural water supplies should be looked at differently than in pure water.

Real-World pH Scale



The figure shows the pH ranges for which the following exist:

1. Free Mineral Acidity (FMA) represents the level of strong (mineral) acids. It occurs when the pH level is below 4.3. Water supplies this low usually are associated with acidic mine drainage, and are considered highly corrosive.
2. Carbon dioxide (CO_2) can exist in water up to a pH of 8.3. A carbon dioxide level of 2 gpg (34 mg/L) or higher is considered corrosive, regardless of the pH.
3. Bicarbonate (HCO_3^{-1}) can exist in a pH range of 4.3 to 10. When the level is expressed in calcium carbonate equivalents (as $CaCO_3$), it is called bicarbonate alkalinity.
4. Carbonate (CO_3^{-2}) can exist above a pH of 8.3. At this pH or higher, there is no carbon dioxide in the water, and therefore no acid. When the level is expressed in calcium carbonate equivalents (as $CaCO_3$), it is called carbonate alkalinity.
5. Hydroxide (OH^{-1}) can exist above a pH of 10. Water supplies with pH this high may affect the skin. When the level is expressed in calcium carbonate equivalents (as $CaCO_3$), it is called hydroxide alkalinity.

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Causes of Water Problems

Problems: Metal corrosion (low pH, high carbon dioxide)
Taste, effervescent (high bicarbonate)
White scale (high pH, high alkalinity)
Dry skin (high pH)

U.S. EPA drinking water standards (secondary):

pH : 6.5-8.5
Free Mineral Acidity: No standard, but FMA exists only below a pH of 4.3.
Hydroxide: No standard, but hydroxide exists only above a pH of 10

Testing on-site: Since carbon dioxide may escape from or dissolve into the water, on-site testing of pH and carbon dioxide is recommended.

Testing in lab: Included in standard water analysis, depending on pH.

Products: Neutralizer with Cullneu® media (low pH, high carbon dioxide)
Soda ash chemical feed (low pH, high carbon dioxide)
Dealkalizer (high alkalinity, high pH, but not over 8.3)
Acid chemical feed (high pH)
Weak-acid cation (carboxylic) resin

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Aluminum

Chemistry: Although dissolved aluminum in water is often considered a cation (Al^{+3}), its actual form depends on the pH of the water:

$Al^{+3} + H_2O = Al(OH)^{+2} + H^+$	cation, very low pH
$Al(OH)^{+2} + H2O = Al(OH)_2^{+1} + H^+$	cation, low pH
$Al(OH)^{+1} + H2O = Al(OH)_3 + H^+$	solid, pH 6.2 – 6.5
$Al(OH)_3 + H2O = Al(OH)_4^{-1} + H^+$	anion, neutral pH
$Al(OH)_4^{-1} + H2O = Al(OH)_5^{-2} + H^+$	anion, high pH
$Al(OH)_5^{-2} + H2O = Al(OH)_6^{-3} + H^+$	anion, very high pH

The above chemical equations indicate aluminum in water exists as a cation when the pH is below 6.2, as a solid (aluminum hydroxide) when the pH is 6.2-6.5, and as an anion when the pH is above 6.5. However, there are no sharp cutoffs regarding pH, since a typical water supply with a pH of 7.2 could contain both aluminum hydroxide and anionic aluminum.

Water supplies with an extreme (especially low) pH level may contain a substantial amount of dissolved aluminum. If the pH of the water is changed toward a pH of 6.5, some of the aluminum will precipitate and the water will turn cloudy. In some applications, there is enough precipitated aluminum to foul water conditioners.

Municipal surface water supplies may have dissolved aluminum due to alum (potassium aluminum sulfate) being fed at the water treatment plant to coagulate and settle fine particles.

Reverse osmosis membranes may become fouled by aluminum because of the pH change that occurs as the water goes through the membrane. Because carbon dioxide, a dissolved gas, goes through the membrane but bicarbonate does not, the pH of the product water typically is lower than the pH of the feed water. This decrease in pH can cause some of the dissolved aluminum to precipitate inside the membrane.

Problems: Turbidity, membrane fouling

U.S. EPA Drinking Water Standard (secondary): 0.05 mg/L (0.2 mg/L if clay material is present)

Testing on site: Available

Testing in lab: Included in standard water analysis.

Products: Acid or soda ash feed to adjust pH to 6.5, followed by filtration.

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Causes of Water Problems

Arsenic

Chemistry: Arsenic exists in water in two possible valences, +3 and/or +5. Both are considered poisons, especially arsenic III.

Arsenic III (arsenite) acts somewhat like aluminum (Al^{+3}), in that it is soluble both at low and high pH levels. Like aluminum, arsenic III is not well reduced by softening or reverse osmosis.

Arsenic V (arsenate, AsO_4^{-3}) acts somewhat like phosphate (PO_4^{-3}). It can precipitate with hardness, and can be reduced by anion exchange or reverse osmosis.

Because water treatment by ion exchange or reverse osmosis is effective only for arsenic V, the normal treatment is to add an oxidizing agent (e.g., chlorine) to the water to oxidize any arsenic III to arsenic V, and then treat the arsenic V. Because arsenic V can be converted back to arsenic III by metals such as copper and iron, the oxidizing agent must remain in the water until just prior to the water treatment equipment that will treat the arsenic.

New iron or alumina based adsorbants can successfully reduce both AsIII and AsV

Problems: Skin damage, circulatory system problems, increased risk of cancer.

U.S. EPA Drinking Water Standard (PRIMARY): 0.050 mg/L (50 parts per billion) NOTE: The Primary Drinking Water Standard is scheduled to be reduced to 0.010 mg/L (10 parts per billion) in 2006.

Testing on site: Available. Test kit must be capable of detecting levels as low as 10 parts per billion.

Testing in lab: The water lab can test for total arsenic by special request. However, the report will not discriminate between arsenic III and arsenic V. Contact the water lab for special sampling instructions if an analysis showing arsenic III and arsenic V is needed.

Products: Chlorine feed followed by dealkalizer or reverse osmosis system. A variety of reverse osmosis drinking water systems are third-party certified for reduction of arsenic V. Culligan is evaluating absorbant media on a feild test basis. Contact Technical Services for more information.

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Asbestos

Chemistry: Asbestos is a naturally occurring fibrous mineral. It is inert and insoluble. The most likely occurrences in water would be surface supplies downstream of discharge from manufacturing processes using asbestos (e.g., asbestos cement plants).

Problems: Lung disease, cancer

U.S. EPA Drinking Water Standard (PRIMARY): 7 MFL (million fibers per liter)

Testing on site: Not available

Testing in lab: Not available. Contact a local laboratory capable of testing for asbestos.

Products: Particulate filtration (whole house), with coagulation as needed. A variety of reverse osmosis and cartridge filter systems are third-party certified for asbestos reduction.

Barium

Chemistry: Barium in water is an ion (Ba^{+2}) with chemical characteristics similar to the hardness ions calcium and magnesium. As such, it can be reduced by ion-exchange softening or reverse osmosis.

Unlike calcium, barium is more likely to precipitate as barium sulfate, which can cause fouling problems for reverse osmosis membranes and, in rare cases, softening resin. If the barium level is known, the sulfate level should also be known to determine if fouling is a potential problem.

Problems: Scale. Higher levels of barium can cause problems with high blood pressure.

U.S. EPA Drinking Water Standard (PRIMARY): 2 mg/L

Testing on site: Not available

Testing in lab: Included in standard water analysis

Products: A variety of softeners and reverse osmosis drinking water systems are third-party certified for reduction of barium.

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Causes of Water Problems

Cadmium

Chemistry: Cadmium in water is a cation (Cd^{+2}) with chemical characteristics similar to zinc. It can be reduced by ion exchange softening or reverse osmosis.

Problems: Kidney damage

U.S. EPA Drinking Water Standard (PRIMARY): 0.005 mg/L (5 parts per billion)

Testing on site: Not available

Testing in lab: The water lab can test for cadmium by special request.

Products: Softener or reverse osmosis system. A variety of reverse osmosis drinking water products are third-party certified for cadmium reduction.

Chloride

Chemistry: Chloride in water is an anion (Cl^{-1}) that is very soluble. It is most commonly associated with sodium, as in table salt, sodium chloride (NaCl). Common sources of chloride include seawater intrusion, road salt, and water softener discharge.

Problems: Salty taste. Hardness minerals diminish the taste, so it is enhanced when the water is softened. Corrosion

U.S. EPA Drinking Water Standard (secondary): 250 mg/L

Testing on site: Available

Testing in lab: Included in standard water analysis

Products: Reverse osmosis. A variety of reverse osmosis drinking water products are third-party certified for TDS/sodium chloride reduction. Polyphosphate chemical feed, where corrosion is a problem.

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Chlorine

Chemistry: Chlorine and its related compounds do not occur in natural water supplies. Rather, chlorine is fed into a water supply to control microorganisms or to oxidize contaminants like iron. Municipal treatment usually involves gas chlorination, while private supplies are treated by feeding a bleach solution.

Free Chlorine. When chlorine gas is fed into water, it forms a solution of hypochlorous acid (HOCl). Bleach is made by introducing chlorine gas into a dilute solution of caustic soda (NaOH), and the net result is sodium hypochlorite. The hypochlorite ion also is called free chlorine, and the concentration is expressed in mg/L as chlorine (Cl_2).

Free chlorine kills microorganisms by passing through the cell wall and interfering with cell metabolism. Hypochlorous acid passes through the cell wall more readily than hypochlorite ion, so sanitization is more effective at a low pH, which favors the formation of hypochlorous acid. Some microorganisms such as Crytosporidia and Giardia form cysts, which have a shell that prevents the passage of chlorine through the cell wall. These microorganisms must be removed by fine filtration.

Chloramines. Some municipal water treatment plants also feed ammonia along with chlorine to form chloramines (combined chlorine). Although chloramines are not as effective at killing microorganisms as is free chlorine, they prevent biogrowth and are more stable in the municipal distribution system. A typical procedure, called breakpoint chlorination, is to feed chlorine in excess with ammonia so that the water leaving the municipal treatment plant contains both free chlorine and chloramines. Often the free chlorine is gone by the time the water reaches the home. In rare cases, the water supply already contains ammonia from fertilizer. Chlorination of such water also will form chloramines.

Chlorinated hydrocarbons. One undesirable potential product of chlorine addition is chlorinated hydrocarbons like trihalomethanes (THM's), that are known to cause cancer. Chlorinated hydrocarbons may form when free chlorine reacts with dissolved organic matter. The level of chlorinated hydrocarbons can be reduced by removing the organic material prior to chlorination, or by using chloramines to reduce the need for high levels of free chlorine. See section on Volatile Organic Chemicals.

Problems: Taste, odor, metal corrosion, harmful to fish

U.S. EPA Drinking Water Standard (PRIMARY): 4 mg/L (Maximum Recommended Disinfectant Level)

Testing on site: Because chlorine and chloramine levels can change after sampling, their levels should be tested on site.

Testing in lab: Available, but not recommended.

Products: Cullar® activated carbon filter or carbon filter cartridge.

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Causes of Water Problems

Chromium

Chemistry: Chromium can exist in water in two forms, Cr III (chromic ion, Cr^{+3}) and Cr VI (chromate ion, CrO_4^{-2}, or dichromate ion, $Cr_2O_7^{-2}$). Cr III can form a variety of complex ions that are not removed by softening. Both Cr III and Cr VI can be reduced by reverse osmosis or deionization.

Problems: damage to liver, kidney, circulatory and nerve tissues; allergic dermatitis

U.S. EPA Drinking Water Standard (PRIMARY): 0.1 mg/L

Testing on site: Available

Testing in lab: The water lab can test for chromium by special request.

Products: A variety of reverse osmosis drinking water products are third-party certified for chromium reduction.

Copper

Chemistry: Copper in water is a positive ion (Cu^{+2}). Unlike many other contaminants, copper usually does not come from the water source. Rather, the copper is a result of corrosion of copper piping. For this reason, the U.S. EPA specifies corrosion prevention as the treatment for copper.

Copper corrosion commonly is associated with water that has a low pH level. However, a more important consideration is the level of carbon dioxide (carbonic acid) in the water. Refer to the section, Acidity and Alkalinity, in this chapter. Acid itself will not corrode copper metal, but it will remove the protective brown copper oxide (Cu_2O) coating, exposing metallic copper to corrosive elements in the water. This reaction is similar to the one that occurs when acid flux is used to prepare copper pipe for soldering. Another potential source of acid is waste products from microorganisms.

The primary cause of copper corrosion is an oxidizing agent like oxygen or chlorine. The oxidizing agent reacts with copper to produce cupric (Cu^{+2}) ions, which color the water blue and produce blue-green stains. A carbon filter can reduce chlorine, but there is no practical method to remove oxygen from a residential water supply. The alternative is to apply a different protective coating by feeding a polyphosphate or polyphosphate/silicate chemical.

Problems: Liver or kidney damage (primary); blue-green stains, metallic taste, green hair (secondary), toxic to fish.

U.S. EPA Drinking Water Standard (PRIMARY): 1.3 mg/L

U.S. EPA Drinking Water Standard (secondary): 1.0 mg/L

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Testing on site: Available. Also see Corrosion Testing in Chapter 4.

Testing in lab: Included in a standard water analysis. Also see Corrosion Testing in Chapter 4.

Products: Softener (if copper is from source); neutralizer, soda ash feed, and/or polyphosphate feed (if copper is from corrosion).

Detergent

Chemistry: Detergents are synthetic organic compounds intended to dissolve oils and greases into water. They were developed as an alternative to soaps to prevent the formation of soap curd when used with hard water. Nevertheless, detergents will react with hardness in the water, resulting in higher detergent usage.

Detergents also may contain phosphates, which are intended to tie up hardness and make the detergent more effective. However, such chemicals in dishwasher detergents may cause problems when used with soft water. When there is no hardness, the chemicals can combine with metal ions in the glassware (metals are added to glass to strengthen it). The first indication of this reaction is a "rainbow" sheen, similar to a thin layer of oil on water. As the metals are removed, the silica glass becomes more susceptible to dissolving in the alkaline detergent in a process called etching. The glassware appears to have a white film on it, but the glass actually is corroding.

Because detergents do not occur in nature, the presence of detergents indicates contamination from the surface. If the water contains detergent, a local health authority should test the water for bacteria.

Problems: Foaming, bad taste/odor, etching of glassware

U.S. EPA Drinking Water Standard (secondary): 0.5 mg/L (foaming agents)

Testing on site: Available

Testing in lab: The water lab can test for detergents by special request.

Products: Activated carbon filter with Cullar® G media. For glassware etching, recommend the following:

1. Use less detergent. Some dishwasher manufacturers include information on the appropriate amount of detergent to use for a given hardness level.
2. Lower the water temperature. Heat accelerates etching.
3. Do not overload the dishwasher. Overloading prevents rinsing residual detergent from the dishware.
4. Consider using a rinse agent to help remove detergent from the glassware.

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Causes of Water Problems

Dissolved gasses

Chemistry: Water can contain a variety of dissolved gasses that can cause problems, including carbon dioxide, hydrogen sulfide, oxygen, and methane. Most occur naturally, but some systems have oxygen introduced due to aeration, contact with air in a storage or pressure tank, or exposure of the water to air after the water has left the tap.

Problems:

Carbon dioxide – (see Acidity and Alkalinity section in this chapter)

Hydrogen sulfide – (see Hydrogen Sulfide section in this chapter)

Oxygen – corrosion, unintended oxidation of iron

Methane – flammable when released from water and the air concentration reaches 5-15%

General – cloudy water, with the cloudiness clearing from the bottom up.

U.S. EPA Drinking Water Standard (PRIMARY): no standard, but water should be non-corrosive and not produce objectionable odors.

Testing on site: Because gasses can escape from a water sample in transit, on-site testing is recommended. See sections covering carbon dioxide or hydrogen sulfide for testing these gasses.

Dissolved oxygen test kits are available, but usually not required. Municipal water supplies and most surface water supplies contain oxygen. A pressure tank with an air/water interface (no bladder) will add oxygen to the water. Aeration or atmospheric storage tank systems also will add oxygen to the water. If none of these apply, then consider testing for dissolved oxygen.

See Chapter 4, Testing, for information on testing for methane on-site.

Testing in lab: Not available, although carbon dioxide is calculated and the result is shown in the DI Calculations section of the water analysis report.

Products:

Dissolved oxygen. Although a reducing agent like sodium hydrosulfite could be used to remove dissolved oxygen, the resulting water would not be potable. The recommended treatment is polyphosphate. When combined with a small amount of hardness (0.5 –1 gpg), the polyphosphate can put a coating on copper piping to prevent contact of oxygen with the metal.

Carbon dioxide. (see section on Acidity and Alkalinity in this chapter)

Methane. Aeration, forced-draft

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Fluoride

Chemistry: Fluoride dissolved in water is an anion (F^{-1}). It occurs naturally in many water supplies, and in some regions at high levels. Many municipal water treatment plants feed fluoride compounds to prevent tooth decay. The typical level of fluoride in such waters is 1 mg/L.

Problems: Bone disease (PRIMARY), brown spotting of teeth in children (secondary)

U.S. EPA Drinking Water Standard (PRIMARY): 4.0 mg/L

U.S. EPA Drinking Water Standard (secondary): 2.0 mg/L

Testing on site: Available

Testing in lab: Included in a standard water analysis.

Products: A variety of reverse osmosis drinking water products are third-party certified for fluoride reduction.

Hardness

Chemistry: Hardness consists of calcium ions (Ca^{+2}) and magnesium ions (Mg^{+2}). Because of their relatively strong charge, +2, they act like strong "magnets" and attract negative ions like carbonate (CO_3^{-2}) and sulfate (SO_4^{-2}) to form scale. Hardness ions also combine with soaps to form a curd.

Other ions in water also have a +2 charge: iron (Fe^{+2}), manganese (Mn^{+2}), copper (Cu^{+2}), zinc (Zn^{+2}), barium (Ba^{+2}), strontium (Sr^{+2}), radium (Ra^{+2}), and lead (Pb^{+2}). Iron and manganese ions cause problems with staining, which is a form of scale. Barium and strontium may form sulfate scales on reverse osmosis membranes. Because these ions can cause similar problems, because they have the same charge as calcium and magnesium, and because a softener also can remove them, these ions also could be considered forms of hardness.

The tendency of a water supply to precipitate hardness scale can be estimated by calculating its Langlier Saturation Index (LSI). The LSI is a function of the levels of calcium, bicarbonate alkalinity, Total Dissolved Solids, pH, and temperature. A positive index indicates calcium carbonate scale will precipitate, while a negative index indicates that calcium carbonate scale will dissolve. The index was developed to determine the effect of water supplies on concrete aqueducts, which will be "corroded" if the LSI is negative. Water with a negative LSI also would dissolve calcium carbonate from concrete pools and tile grout. ***Note:*** *A negative LSI does not mean that the water is corrosive to metal pipe. See the appendices for information on calculating the LSI.*

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Causes of Water Problems

Problems: Scale, soap curd, reduced life of clothing and bedding.

U.S. EPA Drinking Water Standard: none

Testing on site: Available. See section on "Diluting" in Testing chapter.

Testing in lab: Included in a standard water analysis.

Products: Softener.

Hydrogen Sulfide

Chemistry: Hydrogen sulfide (H_2S) is a gas dissolved in water, and can be recognized by its characteristic rotten egg odor.

Although the odor alone is sufficient to identify the presence of hydrogen sulfide, the odor level should not be used to determine the amount. Hydrogen sulfide can separate into hydrogen ions and bisulfide ions:

$$H_2S = H^+ + HS^{-1}$$

Bisulfide ions remain dissolved in water and do not produce an odor. The higher the pH level, the more bisulfide ions, and the lower the odor. Also, the higher the water temperature, the more hydrogen sulfide gas will escape, so the odor will be more noticeable in warmer water.

There are three potential sources for hydrogen sulfide:

1. Decay of underground organic deposits. This source provides a relatively constant level of hydrogen sulfide, although there can be variations due to changes in temperature or atmospheric pressure.
2. Sulfate Reducing Bacteria (SRB's). These are a type of bacteria that ingest sulfate (SO_4^{-2}) and convert it to hydrogen sulfide. This conversion takes time, so the level of hydrogen sulfide will increase as the water sits in the pipes. The odor will be worse at first draw, then decrease as the water is used. Even if the odor is stronger in the hot water, it should also be present in the cold water if it is due to SRB's.
3. Water heater. Most water heaters contain an anode rod made from magnesium (Mg) or aluminum (Al). Any corrosive substances in the water will react with the anode rod instead of the steel heater tank, so the anode rod protects the tank from corrosion. One substance that can react with the anode rod is sulfate (SO_4^{-2}):

$$4Mg + SO_4^{-2} + 10H^+ = 4Mg^{+2} + H_2S + 4H_2O$$

$$8Al + 3SO_4^{-2} + 30H^+ = 8Al^{+3} + 3H_2S + 12H_2O$$

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Sulfate ions are converted to hydrogen sulfide. This conversion takes time, so the level of hydrogen sulfide will increase as the water sits in the water heater. The odor will be worse at first draw, then decrease as the water is used. Unlike hydrogen sulfide due to SRB's, there should not be an odor in the cold water.

Hydrogen sulfide can combine with iron or copper ions to form metallic sulfides (FeS and/or CuS). In addition to causing black stains, metallic sulfides tend to deposit on the inside of the plumbing. During periods of high flow, some of the deposits may come off and go to service. Black particles to service may persist for some time even after the hydrogen sulfide is removed.

Removal of hydrogen sulfide commonly involves oxidation to sulfate ions (SO_4^{-2}). In some applications, the reaction produces elemental sulfur, a fine, sticky, milky-yellow solid. This material can plug pipes, control valves, and media beds.

Problems: Rotten-egg odor, black stains (metallic sulfides). At high concentrations, hydrogen sulfide can be poisonous and flammable.

U.S. EPA Drinking Water Standard (secondary): none, but water should not have an odor.

Testing on site: Recommended. Use a test kit that develops a blue color proportional to the amount of hydrogen sulfide present. The use of a test kit that uses effervescing tablets (e.g., Alka-Seltzer® tablets) is not recommended, due to field reports of inaccurate results. Also see sections on "Diluting" and "Solids Testing" in Chapter 4.

Testing in lab: The water lab can test for hydrogen sulfide by special request, but a special sample bottle is required. Contact the lab at Northbrook for details.

Products: Oxidizing filter (Cullsorb® filter, Super S® filter, Iron-Cleer™ filter) or Cul-Cleer™ system with either chlorine or hydrogen peroxide chemical feed. ***Note:*** *Only a chlorination system will correct a hydrogen sulfide problem due to sulfate reducing bacteria.*

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Causes of Water Problems

Iron

Chemistry: Iron is the most common problem encountered in problem water applications. The problem is made more difficult because iron can exist in a variety of forms, each of which may require a different type of water treatment

Ionic iron consists of two types. Ferrous iron (Fe^{+2}) is the most common type of iron encountered in private well supplies. It also is known as clear water iron or soluble iron, since it has both characteristics. Ferric iron (Fe^{+3}) is uncommon in most water supplies. It is soluble only in water that has a low alkalinity. In such waters, the water may have a yellow (not rust) color. Ferrous iron can be oxidized to ferric iron by oxidizing agents such as oxygen and chlorine. Because municipal water supplies usually contain at least one of these oxidizing agents, they are not expected to contain ionic iron.

Particulate iron (rust, $Fe(OH)_3$ or $Fe_2O_3.3H_2O$) is ferric iron that has precipitated with alkalinity to form a familiar orange-brown stain or scale. There are two basic types of particulate iron, colloidal and filterable. The technical definition of a colloidal particle is one that is so small (0.1 to 0.0001 micron) that molecular collisions are enough to keep it in suspension. For water treatment purposes, a practical definition of a colloidal iron particle is one that is smaller than the filter applied to remove it. From this definition, a filterable iron particle is large enough to be removed by the filter applied to remove it.

Note: *A third type of particulate iron is metallic iron. It comes from deteriorating iron pipe. The black particles of metallic iron are unique in that they are attracted to a magnet.*

A third class of iron is bound iron, and this class also consists of two types, organic-bound and polyphosphate-bound. Organic-bound iron is a combination of iron and a dissolved organic material such as tannin. Polyphosphate-bound iron is a combination of iron and polyphosphate fed by a municipal treatment plant. Neither type of bound iron is removed by ion exchange or iron filters.

Iron bacteria commonly are included in a discussion of iron types. However, treatment for iron bacteria is the same as for many other microorganisms, and iron bacteria should be considered a type of microorganism, not a type of iron.

Problems: Reddish-brown stains, turns beverages black, metallic taste, fouls ion exchange resins

U.S. EPA Drinking Water Standard (secondary): 0.3 mg/L

Testing on site: Testing on site is the only way to determine the type(s) of iron present in the water. See the next chapter, Testing.

Testing in lab: Included in standard analysis. However, the value represents total iron and does not indicate the type(s) present on site.

Products: Ionic iron – softener, iron filter, Cul-Cleer® system with chlorine feed

Particulate iron – depth filter, cartridge filter, Cul-Cleer system with alum feed.

Bound iron – Cullar® activated carbon, macroporous anion resin (organic-bound), macroporous anion resin, hot water cartridge filter (polyphosphate-bound)

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Lead

Chemistry: Lead dissolved in water is a cation (Pb^{+2}). Although it is occasionally present in a natural water supply, the primary cause of lead in water is corrosion of lead piping or lead solder. For this reason, the U.S. EPA specifies corrosion prevention as the treatment for lead. Buildings constructed after 1986 are unlikely to have lead pipe or solder, which were banned by the U.S. EPA.

Problems: Infants and children: Delays in physical or mental development. Adults: Kidney problems; high blood pressure

U.S. EPA Drinking Water Standard (PRIMARY): 0.015 mg/L (15 parts per billion) – action level

Testing on site: Available.

Testing in lab: The water lab can test for lead by special request.

Products: A variety of reverse osmosis drinking water products are third-party certified for lead reduction. A softener can reduce lead levels, but not if the lead is due to corrosion after the softener. A neutralizer, soda ash feed, and/or polyphosphate feed would be used if the lead level is due to corrosion.

Manganese

Chemistry: Manganese exists in water as a cation, Mn^{+2}. It can be oxidized to Mn IV (manganese dioxide, MnO_2) by a variety of oxidizing agents, but the reactions usually are slow unless the pH is above 9. The exception is permanganate, where the reaction is catalyzed by manganese dioxide:

$$Mn^{+2} + MnO_4^{-1} = 2\ MnO_2$$

Some literature indicates soluble manganese can be oxidized by manganese dioxide to form manganic (Mn^{+3}) ions:

$$Mn^{+2} + MnO_2 + 4\ H^{+} = 2\ Mn^{+3} + 2\ H_2O$$

However, the manganic ion is not stable in water. Any manganic ion in water will "auto-oxidize" and convert to soluble manganese and manganese dioxide. Although manganese dioxide can remove soluble manganese by adsorption, this removal typically lasts only about six months.

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Problems: Chocolate-brown to black stains, plugging of pipes with manganese dioxide, black particles to service.

U.S. EPA Drinking Water Standard (secondary): 0.05 mg/L (50 parts per billion)

Testing on site: Available. Also see Solids Testing section in Chapter 4.

Testing in lab: Included in standard analysis.

Products: Softener. Where softening is not practical, the alternative is a continuous-feed (potassium permanganate) Cullsorb® filter.

Mercury

Chemistry: Mercury exists in water as a cation, Hg^{+2}. However, mercury commonly combines with other substances in the water to produce non-ionized or anionic compounds. Mercury also can be bound to organic materials.

Problems: Kidney damage.

U.S. EPA Drinking Water Standard (PRIMARY): 0.002 mg/L (2 parts per billion)

Testing on site: Not available.

Testing in lab: The water lab can test for mercury by special request.

Products: A variety of reverse osmosis drinking water products are third-party certified for mercury reduction. Because mercury can combine with a variety of substances, ion-exchange is not recommended for removal.

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Microorganisms

Biology: Microorganisms are small forms of animal or plant life that exist in water or air. Examples include bacteria, cysts, molds, fungi, and algae. Most microorganisms are harmless, and some are beneficial.

Some microorganisms are considered nuisances, but not harmful. Examples include:

Iron Bacteria. This type of bacteria forms stringy masses in toilet tanks and can plug faucet aerators. NOTE: Iron bacteria is a form of bacteria, not a form of iron. Do not confuse iron bacteria with organic bound iron.

Sulfate Reducing Bacteria (SRB). (see section on Hydrogen Sulfide).

Algae. Algae are a variety of microscopic plants that commonly occur in surface water. They cause green, blue-green, or brown deposits. The problem is especially evident in clear tubing or clear filter bowls, since alga growth requires sunlight.

"Pink" Microorganisms. A variety of microorganisms can cause a bright pink stain, usually in toilet bowls or showerheads. A common microorganism is ***Serratia marcescens***, an airborne bacterium found in soil. When new construction or other activity stirs up dust, the bacteria can travel to a moist environment like a bathroom.

The microorganisms of greatest concern are those that cause health problems. Examples include:

Coliform bacteria. Municipal water plants and local health departments monitor water for total coliform and fecal coliform bacteria. Although a positive test for total coliforms does not necessarily mean the water contains disease-causing microorganisms (pathogens), it requires that the water be tested for fecal coliforms. The presence of fecal coliforms or ***E. coli*** indicates the water has been contaminated by sewage.

Cysts. Certain microorganisms form an outer shell for protection against harsh environments. When the environment becomes favorable, the shell dissolves and the microorganism can grow. Two examples of cyst-formers are Giardia lamblia and Cryptospridium.

Viruses (enteric). Enteric viruses cause intestinal illnesses.

Problems: Gastrointestinal illness, sometimes resulting in death.

U.S. EPA Drinking Water Standard (PRIMARY): Rather than specifying a maximum contaminant level, the standard refers to Treatment Techniques (TT's). Treatment involves disinfection and filtration to remove/inactivate Cryptosporidum by 99%, Giardia lamblia by 99.9%, and viruses by 99.99%. If there is a positive test for Total Coliform, the water should be tested for fecal coliform. A second positive test for Total Coliform, or a positive test for fecal coliform, indicates disinfection is required.

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Testing on site: Field test kits are available for a variety of nuisance organisms such as iron bacteria and sulfate reducing bacteria. Coliform bacteria tests usually are performed by local laboratories, such as a county health service.

Testing in lab: Not available.

Products: The primary treatment for most microorganisms is chlorination. For private wells, the well should be shock chlorinated and then re-tested. The well should be inspected for potential surface water intrusion due to flooding or a bad well casing. If regrowth occurs too often for shock chlorination, continuous chlorination would be required. A continuous chlorination system consists of a chlorine feeder and contact tank.

Chlorination will not destroy cysts, but cysts are relatively large particles that can be filtered. A variety of drinking water systems are third-party certified for cyst reduction. Since cysts usually are found in surface water supplies containing other microorganisms, disinfection is required before or after the cyst filtration system.

Ultraviolet systems also can be used to control microorganisms. Since there is no disinfectant residual after the UV treatment, the system requires proper pretreatment and monitoring to ensure an adequate UV dosage when the water is in the UV chamber.

Nitrate/Nitrite

Chemistry: Nitrate (NO_3^{-1}) and nitrite (NO_2^{-1}) are both anions. Nitrate is very soluble in water, so there are no mineral deposits in the United States containing nitrate. The most common source of nitrate is fertilizer, although nitrate also is associated with sewage. If nitrate or nitrite is detected at any level in the water, the water should be tested for coliform bacteria (see section on Microorganisms).

Nitrite is the reduced form of nitrate. When exposed to air, it oxidizes easily to nitrate.

Problems: When ingested by infants or certain livestock, nitrate is converted to nitrite in the digestive system. Nitrite can reduce the ability of blood to carry oxygen. An infant will turn blue and have shortness of breath ("Blue Baby Syndrome"). These symptoms may result in death.

U.S. EPA Drinking Water Standard (PRIMARY): 10 mg/L nitrate as nitrogen (N); 1.0 mg/L nitrite as nitrogen (N). NOTE: Certain states may have drinking water standards expressed as nitrate and nitrite rather than as nitrogen. Comparable standards would be 45 mg/L nitrate as NO_3, and 3.3 mg/L nitrite as NO_2.

Testing on site: Available. Because it may convert to nitrate after sampling, nitrite testing should be done on site. Since the nitrate comes from surface water, the concentration is likely to change over time due to variations in fertilizer application and rainfall.

Testing in lab: Included in standard analysis.

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Products: A variety of reverse osmosis drinking water products are third-party certified for nitrate and nitrite reduction. For whole-house nitrate/nitrite reduction, reverse osmosis or nitrate-specific resin units are alternatives. Whichever system is used, the nitrate levels of the untreated and treated water must be monitored regularly.

Petroleum

Chemistry: Petroleum is a general term for oils, gasoline, greases, and similar hydrocarbons. Crude oil is produced from the decay of organic materials deposited in seawater, so it often is associated with water that has a high TDS level. Refined oil and gasoline in water is a result of contamination from industrial discharge, spills, and storage tank leakage.

Refined petroleum products often contain additives such as MTBE and other volatile organic chemicals (VOC's). See section on Volatile Organic Chemicals.

Problems: Oily taste or odor. If the concentration is high enough, petroleum products will form a film on top of the water surface. Petroleum can foul water treatment media.

U.S. EPA Drinking Water Standard: none

Testing on site: A rough test for petroleum can be performed using a camphor stick, which should be available at a local pharmacy. Using a knife, place a few thin shavings of camphor on the surface of the water. If the water has an oily film on the surface, the shavings will remain stationary as the camphor dissolves into the oil. If there is no oily film, the shavings will spin due to camphor fumes evaporating into the air.

Testing in lab: The water lab can test for elevated (mg/L or ppm) levels of petroleum by special request. For low (µg/L or ppb) levels, contact the water lab for more information.

Products: Activated carbon filter with Cullar® G media. For portable exchange carbon filters, a top dressing of diatomaceous earth will soak up some petroleum and extend the life of the carbon.

Note: *Do not feed chlorine into water containing petroleum, which may react with the chlorine to form chlorinated hydrocarbons.*

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Causes of Water Problems

Radionuclides

Chemistry: Atoms contain an internal structure, or nucleus, that contains protons and neutrons. For atoms of some elements, radionuclides, the nucleus is not stable and it eventually breaks down. During this process, a new element is formed, and one or more types of radiation are emitted:

Alpha radiation, consisting of helium nuclei (two protons and two neutrons)

Beta radiation, or electrons

Gamma radiation, consisting of high-energy photons (e.g., x-rays)

Although a variety of elements are considered radioactive, the three elements normally encountered in water treatment are radium (Ra), radon (Rn), and uranium (U).

Radium in water exists as a cation (Ra^{+2}). Other than radioactivity, it has properties similar to calcium and magnesium.

Radon is an inert gas that does not form an ion in water nor react with other atoms or molecules.

Uranium chemistry is relatively complex. Under anaerobic (no oxygen, reducing) conditions, the predominant form likely is U^{+4}, which likely complexes with carbonate or hydroxide. Under aerobic (oxygen, oxidizing) conditions the predominant form is the uranyl ion, UO_2^{+2}, which complexes at higher pH levels with carbonate to form uranyl dicarbonate ($UO_2(CO_3)_2^{-2}$) and uranyl tricarbonate ($UO_2(CO_3)_3^{-4}$).

Problems: Increased risk of cancer.

U.S. EPA Drinking Water Standard (PRIMARY): Radium, 5 pCi/L (picocuries per liter); Uranium, 0.030 mg/L (30 parts per billion, as of December 8, 2003). NOTE - Additional primary standards for radioactive substances include: Alpha particles, 15 pCi/L; Beta particles and photon emitters, 4 millirems/year. In order to treat the water, the source of the alpha and/or beta radiation must be known.

Testing on site: Not available.

Testing in lab: The water lab does not test for radioactive substances. Contact a local laboratory capable of such testing.

Products: Radium. A variety of softeners and reverse osmosis drinking water systems are third-party certified for radium reduction.

Radon. Radon in water can be reduced by about 50% with a forced-draft aeration system. Although activated carbon also can reduce the radon level, its use is not recommended due to radioactive emissions (gamma) from the carbon.

Uranium. Aeration or chlorination to oxidize any U^{+4}, followed by a chloride anion dealkalizer to remove uranyl carbonate ions can reduce uranium. However, the pH of the water must be maintained above 7.5 at all locations. If the water entering the dealkalizer has a pH below 8, it may contain enough carbon dioxide to lower the pH of the treated water below 7.5, and allow some uranium to pass to service. This decrease in pH can be avoided by feeding soda ash with the chlorine, regenerating the dealkalizer with caustic as well as salt, or by adding soda ash to the dealkalizer brine tank. Regeneration frequency should be based on total anion loading.

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Selenium

Chemistry: The chemical properties of selenium (Se) are similar to those of sulfur. It can exist as hydrogen selenide (H_2Se), elemental selenium (Se_8), and selenate (SeO_4^{-2}). Unlike with sulfur, oxidation is not an acceptable treatment method, since the selenate ion still would be considered a health hazard.

Problems: Hair or fingernail loss, numbness in fingers or toes, circulatory problems.

U.S. EPA Drinking Water Standard (PRIMARY): 0.05 mg/L (50 parts per billion)

Testing on site: Not available

Testing in lab: The water lab can test for selenium by special request.

Products: A variety of reverse osmosis drinking water systems are third-party certified for reduction of selenium.

Silica

Chemistry: Silicon (Si) is the second most common element in the earth's crust. When combined with oxygen, it forms a wide variety of silicates, including quartz and other minerals found in rocks. Water treatment is concerned with two types of silicates, dissolved silica and insoluble silica.

Dissolved silica includes metasilicate ions (SiO_3^{-2}) and orthosilicate ions (SiO_4^{-4}).

Dissolved silica also is known as reactive silica, since these ions will react with test chemicals.

The solubility of reactive silica is dependent on temperature. The approximate solubility may be calculated as follows:

Solubility = (2 x Temperature, °C) + 75

For example, assume a water temperature of 55°F, or 12.8°C. The solubility of silica would be

Solubility = (2 x 12.8) + 75 = 100.6 mg/L

If soluble silica is concentrated in this water (on the waste side of an RO element, or in a drop of water that is evaporating), silica will precipitate when the concentration exceeds about 101 mg/L.

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Insoluble silica refers to particles of sand, clay, or other minerals. Particulate matter is covered in the section, "Suspended Solids".

Problems (reactive silica): Spotting, especially when the level exceeds 25 mg/L. Fouling of reverse osmosis membranes.

U.S. EPA Drinking Water Standard: None

Testing on site: Available (reactive silica).

Testing in lab: Reactive silica is included in a standard water analysis.

Products: Reactive silica is rejected by reverse osmosis membranes, but may cause scale problems in the waste water. In most cases, adjusting the recovery of the reverse osmosis system can prevent the silica scale. Although reactive silica is anionic, only strong-base anion resin will remove it, and only when the resin is regenerated with caustic (a deionizer).

Sodium

Chemistry: Sodium in water is a cation (Na^{+1}). It is very soluble in water, and therefore is present in most water supplies.

High levels of sodium often are associated with seawater, which contains sodium at a level of about 13,000 mg/L. Near a seacoast, salt water may intrude into the water supply. A shallow sea once covered the central United States; salt deposits remaining after the seas evaporated can increase the sodium level. Since petroleum deposits also were formed in this sea, high sodium levels also are associated with oil wells.

Problems: Taste and spotting are covered in the section, Total Dissolved Solids.

Sodium in the Diet. Some individuals are on low-sodium diets due to congestive heart failure or hypertension. Even if they are not on a restricted diet, some individuals have expressed concerns about increased sodium in softened water. These concerns should be addressed, not dismissed, since one purpose of water treatment is to increase the customer's quality of life.

The first step in addressing concerns about the sodium level is to determine the sodium level in the untreated water. This is best done via a water analysis. Use the "as element" value, not the "as $CaCO_3$" value.

Next, determine the total hardness in the untreated water. A softener will add the same amount of sodium, in grains per gallon as $CaCO_3$, to the water. Multiply this value by 7.866 to convert it to mg/L as the element sodium.

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Finally, add the value for sodium in the raw water to the value for sodium added by the softener. The result is the level of sodium in the softened water.

Example: The sodium level from the water analysis is 61 mg/L as sodium. The Total Hardness is 6.3 gpg, so the sodium added by softening would be (6.3 x 7.866 =) 50 mg/L as sodium. The total sodium in the softened water would be (61 + 50 =) 111 mg/L.

Dietary intake generally is expressed in milligrams (mg). The U.S. EPA estimates the average daily intake is two liters, so multiplying the sodium level by two results in the daily sodium intake from water. Using the example above, the daily dietary intake would be (2 x 111 =) 222 mg.

Once the sodium intake due to water has been determined, it can be compared to sodium intake from other sources. Many food containers now have nutrition information labels, including the milligrams of sodium per serving. According to these labels, the recommended daily value for sodium intake is 2400 milligrams. Use the information from the nutrition labels (using containers supplied by the customer, if possible) to determine daily sodium intake. A table showing the sodium content of a variety of foods is shown in the appendices.

If the amount of sodium in the water is determined to be too high, it can be reduced by a reverse osmosis drinking water system.

Plants. Grass, shrubs, trees, and flowers may be damaged if they are watered with water that is high in sodium. As water evaporates from the soil, the sodium in the remaining water becomes more concentrated. A high concentration of dissolved solids will prevent plant roots from taking in water. If there is adequate rainfall, the dissolved solids will be diluted. If potted plants are watered thoroughly so that water flows from the bottom of the pot, the dissolved solids will be rinsed from the soil.

Humidification. Humidifiers add moisture to the air through evaporation. As water evaporates, the dissolved solids level increases in the remaining water. With hard water, this results in calcium carbonate scale coating the reservoir and filter pad. Although soft water will not form scale as quickly as hard water, eventually the dissolved solids concentration becomes high enough for sodium salts to form scale. Sodium scale can be blown out of the humidifier and produce a sodium "dust". If this occurs, the reservoir should be drained and refilled with fresh water. A better solution would be use reverse osmosis to treat the water for the humidifier.

U.S. EPA Drinking Water Standard: none. NOTE: Some states have established maximum levels for sodium.

Testing on site: Not available. A rough estimate of the sodium level can be obtained by subtracting the total hardness level from the Total Dissolved Solids level. All values should be in mg/L as calcium carbonate. To convert the value to mg/L as sodium, multiply by 0.46.

Testing in lab: Included in a standard water analysis.

Products: Reverse osmosis, deionizer.

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Causes of Water Problems

Strontium

Chemistry: Strontium in water is an ion (Sr^{+2}) with chemical characteristics similar to the hardness ions calcium and magnesium. As such, it can be reduced by ion-exchange softening or reverse osmosis.

Unlike calcium, strontium is more likely to precipitate as strontium sulfate, which can cause fouling problems for reverse osmosis membranes. If the strontium level is known, the sulfate level should also be known to determine if fouling is a potential problem.

Problems: Fouling of reverse osmosis membranes.

U.S. EPA Drinking Water Standard: None

Testing on site: Not available.

Testing in lab: Included on a standard water analysis.

Products: Softener.

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Sulfate

Chemistry: Sulfate in water is an anion (SO_4^{-2}). It is dissolved from deposits of gypsum (calcium sulfate), which is known for its use in drywall. Sulfate also forms from the oxidation of hydrogen sulfide. The oxidation of hydrogen sulfide in coal mines results in the formation of sulfuric acid, so the pH of water from coal mines typically is very low.

Problems: Levels above the drinking water standard may cause a bitter taste. Higher levels also may cause a laxative effect in humans and livestock (scours). As sulfate becomes more concentrated in reverse osmosis waste water or a humidifier reservoir, it may precipitate with calcium, barium, or strontium to form an insoluble scale.

U.S. EPA Drinking Water Standard (secondary): 250 mg/L

Testing on site: Available

Testing in lab: Included on a standard water analysis.

Products: A variety of reverse osmosis drinking water systems are third-party certified for reduction of sulfate. Whole-house reduction of sulfate can be accomplished by a larger reverse osmosis system, or by a chloride anion dealkalizer, which replaces sulfate with chloride.

Suspended Solids

Chemistry: The term, suspended solids, refers to materials in water that are solid rather than dissolved. The most common suspended solid is rust, but others include sand, clay, and even microorganisms. Although the exact composition of the solids usually is not important, knowing the density and particle size is.

Some types of suspended solids, like sand, are too dense to remain suspended in the water very long. These dense solids also are difficult to backwash out of a depth filter, which eventually becomes plugged. If the suspended solids settle from the water in less than a minute, a centrifugal separator should be used to remove them. NOTE: A centrifugal separator will remove only those particles that settle rapidly.

There are two general classes for particle size, filterable and colloidal. Filterable solids are those that are larger than the micron rating of the filter used to remove them. Colloidal solids are those that are smaller. Therefore, the classification will depend on the filter chosen. A depth filter is rated to remove particles with a nominal diameter of 10 microns (10µ), while some cartridge filters have a rating as fine as 0.35 micron.

In some rare cases, the concentration of suspended solids is important. If the concentration is too high, a depth filter may become plugged before it has a chance to regenerate. For example, with a water usage of 400 gallons a day and a 9" Filtr-Cleer depth filter, the suspended solids limit would be about 800 mg/L.

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Causes of Water Problems

Problems: Cloudiness (turbidity); plugging; deposits in sinks and toilets; interference with disinfection, especially ultraviolet systems.

U.S. EPA Drinking Water Standard: None

Testing on site: Not available. NOTE: Many surface water supplies appear to be clear, but they contain a substantial amount of fine suspended solids that may foul a reverse osmosis element. The fouling potential can be measured in the field using a Silt Density Index (SDI) test kit, Cat. No. 00-4483-20. This test is highly recommended when applying commercial elements of 4" diameter.

Testing in lab: The water lab can test for suspended solids by special request. Specify a "depth filter analysis." The report will show suspended solids larger than 10 microns ("suspended coarse"), suspended solids between 0.45 microns and 10 microns ("suspended fine"), and Total Suspended Solids, as well as turbidity before and after 10 micron filtration.

Products: Centrifugal (cyclone) separator for dense suspended solids like sand. Depth filter. Particulate cartridge filter. A variety of reverse osmosis drinking water systems and carbon block cartridge filters are third-party certified for reduction of cyst particles, but they will require pretreatment to remove other suspended solids.

Tannins

Chemistry: "Tannins" is a general term for dissolved organic material from the decay of plants. Examples of these relatively large organic molecules include tannic acid, humic acid, and fulvic acid. The familiar yellow-brown color in tea is due to tannins.

When iron and tannins are present in a water supply, the tannins may bind with the iron to form organic-bound iron (see section on Iron).

Problems: Yellow-brown color. At high levels, tannins may form an oily film on the water surface.

U.S. EPA Drinking Water Standard (secondary): None, but color standard is 15 color units.

Testing on site: Available.

Testing in lab: Included in a standard water analysis if the color level is higher than 5 color units.

Products: Activated carbon filter with Cullar® D media. Macroporous anion resin system. NOTE: The type of tannins will depend on the type of decaying organic material, which will differ from region to region. CS-5 resin is known to work well in Florida, while Macro-T resin is recommended for northern states. A Cul-Cleer™ system with alum coagulation, retention, and particulate filtration may be needed for large amounts of tannins. Chlorination has not proven to be effective for tannin reduction due to the large amount of contact time (hours) required.

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Total Dissolved Solids

Chemistry: Total Dissolved Solids (TDS) most commonly refers to the level of dissolved ions in water. Although pure water does not conduct electricity very well, ions dissolved in the water do conduct electricity. The more ions are dissolved in water, the higher the conductivity. The conductivity is measured by a meter to give a reading in microSiemens/cm (µS/cm) or, on older meters, micromhos/cm (µmhos/cm). Using an internal multiplier of about 0.55, TDS meters give readings in mg/L or ppm.

Some ions conduct electricity better than others. For example, sodium ions will conduct electricity better than an equivalent level of calcium ions. This is why softened water typically will have a higher conductivity than the hard water. Silica ions do not conduct electricity very well at all. Therefore, TDS by conductivity is an estimate of the actual level of dissolved ions.

Another method to determine TDS is to measure the levels of all the ions in the water, then add the values. This is the most accurate method for determining the TDS level of dissolved ions, but it requires a complete water analysis.

Although less common, Total Dissolved Solids also can refer to the level of all dissolved substances in water, including non-ionic material (usually dissolved organics). This TDS is measured by filtering a water sample to remove suspended solids, evaporating the water, and weighing the remaining material.

Problems: Bad taste. The type of anion present is the primary cause of the taste:

Chloride – salty
Sulfate – bitter
Bicarbonate – astringent

High hardness tends to mask the taste, while low hardness tends to enhance it.

Scale and spots are caused by high TDS. Although softening will decrease the amount of scale in many cases, spotting still would be a problem when the water evaporates. However, soft water spots are significantly easier to remove than hard water spots.

High TDS also can accelerate corrosion.

U.S. EPA Drinking Water Standard (secondary): 500 mg/L

Testing on site: A variety of TDS meters are available.

Testing in lab: The conductivity, the estimated TDS by conductivity, total cations, and total anions values are included in a standard water analysis.

Products: A variety of reverse osmosis drinking water systems are third-party certified for TDS reduction. Series B reverse osmosis systems are available to reduce the TDS level in the water for the whole house.

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Causes of Water Problems

Turbidity

Chemistry: Turbidity is a measurement of the cloudiness of the water. It is measured by shining a beam of light through the water. A photocell, located at 90 degrees to the light beam, measures the amount of light reflected off the particles suspended in the water. The result is compared to a standard and reported in Nephalometric Turbidity Units (NTU). Because the reflectance of the particles is dependent on their shape and color, turbidity cannot be directly related to the amount of suspended solids in the water. The turbidity value may be masked if the particles are non-reflective (e.g., black).

Problems: Cloudiness. Interference with transmission of disinfecting UV light. May indicate the presence of large amounts of microorganisms.

U.S. EPA Drinking Water Standard (PRIMARY): The standard is a Treatment Technique for water treatment plants requiring that the turbidity never exceed 1 NTU, nor 0.3 NTU in 95% of daily samples any month. The standard applies to systems using surface water or ground water under the direct influence of surface water.

Testing on site: Available, but expensive.

Testing in lab: Included in a standard water analysis. Turbidity values are reported for the sample as received and after 10-micron filtration. The second value indicates the approximate turbidity after a depth filter. NOTE: If the sample contains iron, the turbidity value may not be valid. The turbidity may be caused by iron that oxidized while the sample was in transit.

Products: Depth filter, cartridge filter, or Cul-Cleer™ system with alum feed, retention, and filtration.

Volatile Organic Chemicals

Chemistry: The term Volatile Organic Chemicals (VOC's) refers to a wide variety of organic chemicals.

Some of these chemicals are the result of disinfection processes like chlorination, and are referred to as Disinfection Byproducts (DBP's). Chlorine can react with organic molecules like methane or tannins to produce dichloromethane, trichloroethane, and other suspected cancer-causing chemicals. Other chemicals, like Methyl Tertiary Butyl Ether (MTBE) come from gasoline spills. Still others come from pesticide or herbicide leaching into an aquifer (e.g., atrazine). For a list of the chemicals, refer to the U.S. EPA drinking water standards list in the appendices.

Problems: Many of these chemicals are associated with cancer, kidney problems, and liver problems (refer to the U.S. EPA drinking water standards list in the appendices).

U.S. EPA Drinking Water Standard (PRIMARY): (refer to the U.S. EPA drinking water standards list in the appendices)

Testing on site: Not available.

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Testing in lab: Not available. Contact a local laboratory capable of analyzing these substances.

Products: Activated carbon. A variety of carbon cartridge systems are third-party certified for reduction of specific volatile organic chemicals. For whole-house treatment, the recommended carbon is Cullar® CC media, a coconut-shell carbon. The minimum carbon volume should be one cubic foot for every gallon per minute of flow rate. The carbon volume should be split equally between two tanks in series, and sampling valves should be installed before, between, and after the tanks. A typical residential application will have two 12" portable exchange carbon filters in series, each with 2.5 cubic feet of Cullar CC media. Arrangements should be made for monitoring contaminant breakthrough. When the carbon in the first tank is exhausted, the second tank should become the primary tank, and a fresh carbon tank should be placed in the second position. ***Note:*** *The exhausted carbon may have to be handled as hazardous waste.*

Zinc

Chemistry: Zinc in water is a cation (Zn^{+2}). It rarely occurs at significant levels in natural water. Rather, zinc in water usually is due to corrosion of galvanized iron plumbing or brass fixtures.

Problems: Bitter taste.

U.S. EPA Drinking Water Standard (secondary): 5 mg/L

Testing on site: Available

Testing in lab: Included on a standard water analysis

Products: Softener (but not if zinc is due to corrosion). Neutralizer or soda ash feed if the carbon dioxide level is high (see section on Acidity and Alkalinity). Polyphosphate feed. Also see Corrosion Testing in Chapter 4.

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Chapter 4

Laboratory Water Analysis

The water analysis laboratory at Northbrook offers a variety of analyses, the most common of which is a "standard" analysis. An example of a standard analysis is shown on the following pages. Problems associated with individual constituents are described in Chapter 3, so this section describes parameters associated with the analysis.

Dimensions

The term "dimensions" refers to how the levels are reported.

The turbidity dimension is Nephalometric Turbidity Units (NTU). The unit is based on a set of standards of specific cloudiness. Turbidity after filtration is measured after filtering the sample through a nominal 10-micron filter.

The conductivity dimension is micromhos/centimeter (µmhos/cm), a measure of how well the water sample conducts electricity. A higher conductivity indicates the level of dissolved ions in the water, so it is used to calculate the estimated TDS by conductivity, which is reported in milligrams/liter (mg/L).

The color dimension is Color Units (CU), and is based on a set of standards of specific yellow colors. If the color is higher than 5 CU, the sample is acidified and re-tested. A decrease in color indicates it was due to colloidal iron. Color remaining after acidification likely is due to tannins or other dissolved organic material. ***Note:*** *Colors other than yellow (e.g., blue) will not be reported accurately.*

The pH dimension is pH units.

All other values are reported in milligrams per liter (mg/L), micrograms per liter (µg/L), or grains per gallon (gpg). One liter of pure water weighs one million milligrams, so 1 mg/L is the same as one part per million (ppm). One liter of water weighs one billion micrograms, so 1 µg/L is the same as one part per billion (ppb). For conversion, use the following table:

To convert from	To	Multiply by
PPM	PPB	1000
PPB	PPM	0.001
GPG	PPM	17.1
GPG	PPB	17,100
PPM	GPG	0.058
PPB	GPG	0.000058

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Conversion Factors

Many of the values for cations (positive ions) and anions (negative ions) are reported both "as element" and "as $CaCO_3$".

The values reported as the element are used for comparison to standards. For example, if the chloride level as element is over 250 mg/L, it exceeds the U.S. EPA secondary drinking water standard for chloride.

The values reported as calcium carbonate equivalents are used for ion exchange calculations. Ion exchange involves the charge on the ion, not the weight. For example, a softener will replace one calcium ion (Ca^{+2}, weight 40.1) or one magnesium ion (Mg^{+2}, weight 24.3) with two sodium ions (Na^{+1}, weight 23.0 each). To calculate capacity, the “as element” values must be converted to equivalent weights, which consider both the element weight and the ionic charge. By convention, the water treatment industry uses calcium carbonate ($CaCO_3$) equivalents.

The general calculations for the conversion factors are

$$\text{Conversion factor, as element to as } CaCO_3 = \frac{50}{\text{Ionic weight/charge}}$$

$$\text{Conversion factor, as } CaCO_3 \text{ to as element} = \frac{\text{Ionic weight/charge}}{50}$$

For example, calcium has an ionic weight of 40.1 and a charge of 2. The conversion factor, as element to as $CaCO_3$, is (50/(40/2) =) 2.5. To convert from as $CaCO_3$ to as element, the conversion factor is ((40/2)/50 =) 0.4. Note that these values are reciprocals. The number 50 is the equivalent weight of calcium carbonate.

Calculating conversion factors requires knowledge of ionic weights and charges. The calculations become more complicated when an ion can have more than one charge, like iron (Fe^{+2}, Fe^{+3}). A table of common conversion factors is located in the appendices.

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Additional Information

The top of page 2 of the certificate of analysis shows those parameters that exceed the U.S. EPA Primary (health-related) and Secondary (aesthetics-related) drinking water standards. This information serves to highlight particular problems. However, the standards change regularly, and new standards may be in effect when you review the analysis. To obtain the latest information, visit the EPA website, http://www.epa.gov/safewater/mcl.html.

The middle of page 2 of the certificate of analysis shows typical concentration of certain ions in reverse osmosis product water, based on the concentrations in the feed water. Higher feed pressure and pH, and lower feed TDS and % recovery (lower ratio of product water to feed water) generally result in lower concentrations in the product water.

The DI Calculations are used to determine capacity and quality from a deionizer system. Because of the work involved in using these numbers for sizing, most applications now are sized by entering the analysis information directly into the deionizer section of the CAAP® (Computer Aided Application Program) software.

Other Analyses

In addition to standard analyses, the water lab can test for a variety of water parameters. The most-requested additional test is Total Organic Carbon (TOC). The TOC result represents all organic carbon in a water sample, including tannins, petroleum, and microorganisms. Values over 3 mg/L are considered high enough to foul standard anion resin.

In some applications, the unknown substance is a solid, rather than water. The most common examples are hardness scale and rust. The water lab can test the solid material if enough is available. At least a teaspoon of material is required. Also see the section on field testing of solids.

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Testing

Report 7/8/02 Page 1 of 2

CERTIFICATE OF ANALYSIS

ANALYSIS NUMBER:0201234 Control

Culligan Water Conditioning Customer JAN ANNETTE

123 Main St.

Anytown, USA 98765

Zip 98765

Account 56789

Customer Account

Salesperson CDF cc:

SAMPLE

Analysis Type Standard A Analysis

Sampled:	6/20/02	Supply/Source:	PRIVATE WELL	Condition:	UNTREATED
Received:	6/25/02	Sampling	PRESSURE TANK	Application:	Household

ANALYSIS INFORMATION:

Turbidity(Method 180.1)	40.8 NTU	Turbidity after filtration	7.7
Conductivity(Method	610.0 MMHOS/CM	Est. TDS by Conductivity	399.9
Color(Method 2120C)	6.5	Color after Acidification	5.2
pH(Method 150.1)	6.7	Tannins	N.D.

Concentrations reported as mg/L (PPM) unless otherwise noted

CATIONS (Method 200.7)			**ANIONS (Method 300.0)**		
	As Element	As $CaCO_3$		As Element	As $CaCoO_3$
Calcium (Ca)	65	162.5	Chloride (Cl)	1.7	2.4
Magnesium (Mg)	30.6	126.1	Nitrate/Nitrite (N)	N.D.	N.D.
Sodium (Na)	1.2	2.6	Sulfate (SO_4)	239	248.6
Potassium (K)	2.1	2.7	Bicarbonate (HCO_3)	37.9	31.0
Strontium (Sr)	0.1	0.1	Carbonate	N.M.	N.M.
Barium (Ba)	0.04869		Fluoride (F)	0.2	0.50
Iron (Fe)	3.56		Silica (SiO_2)	33.9	
Manganese (Mn)	0.23				
Copper (Cu)	1.661				
Zinc (Zn)	6.49				

	Mg/L	GPG		Mg/L	GPG		Mg/L	GPG
Cations	293.9	17.19	Anions	282.6	16.52	Hardness ($CaCO_3$)	289	16.9

Additional Tests

Aluminum by ICP 145.00ug/L

*NA = Not Analyzed NM = Not Measured ND = Not Detected

This report can only be reproduced in its entirety. The results reported here are representative of the sample as received in the laboratory. Testing is in compliance with current NELAP requirements

State Laboratory Certifications: CA- 01133A; IL -000280; NY- 11756

Richard Cook

Manager Analytical Laboratory

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Analysis 0201234
Consumer JAN ANNETTE

FEDERAL SAFE DRINKING WATER

All tested parameters exceeding the maximum contaminant levels (MCL) established by the "Federal Safe Drinking Water Act".

	Parameter	Found	MCL
PRIMARY	Turbidity	40.8 NTU	0.50 NTU
SECONDARY	Zinc (Zn)	6.49 mg/l	5.00 mg/l
	Manganese (Mn)	0.23 mg/l	0.05 mg/l
	Iron (Fe)	3.56 mg/l	0.30 mg/l
	Copper (Cu)	1.66 mg/l	1.00 mg/l
	Aluminum by ICP	0.14 mg/L	0.05 mg/L

* MCL for Turbidity varies as follows:

1. Municipal Direct Filtration 0.5 NTU
2. Municipal Sand Filtration 1.0
3. Unfiltered Water 5 NTU

TYPICAL POST RO DRINKING WATER UNITS

(Concentrations reported as mg/L (PPM) as the element)

Calcium (Ca)	1.3	Iron (Fe)	0.2
Magnesium (Mg)	0.6	Manganese (Mn)	0.0
Sodium (Na)	0.0	Zinc (Zn)	0.1
Potassium (K)	0.0	Copper (Cu)	0.0
Chloride (Cl)	0.1	Nitrate/Nitrite	0.0
Sulfate (SO4)	2.4	Fluoride (F)	0.0

These values are typical of new modules on water with a pH of 7-9 at 70-74 F with 500-3000 salts operating with 40-70 PSI pressure across the module. Local conditions may yield different results.

DI CALCULATION

			GPG	mg/l
Sodium	0.9%	Weak Base Fact X	14.7	251.3
Alkalinity	13.4%	Carbonic Acid	4.2	71.1
Chloride	0.9%	Cation Fact Y	17.2	294.0
Carbonic Acid	16.1%	Silica	1.6	28.15
Monovalent Ions	0.7%	Carbon Dioxide	1.0	16.6
Silica	10.0%	Strong Base Fact Z	19.8	339.4

Analysis

Method	**Date**	**Method**	**Date**
120.1	06/28/02	150.1	06/28/02
180.1	06/27/02	200.7	06/29/02
2120C	06/27/02	300.0	06/27/02

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Testing

Field Testing

In many applications, the best, or only, way to test for a specific parameter is on-site. This particularly applies to parameters that many change while the sample is in transit. Examples include chlorine, hydrogen sulfide, methane, carbon dioxide, and iron.

Diluting

Before starting a test, determine if the test procedure develops a color that is compared to color standards on a label, chip, cube, or wheel, and the resulting value is in mg/L or gpg. If the developed color is at or near the upper limit of the color standard, the actual concentration may be above the limit. Dilute the sample with deionized water and re-test until the concentration value is in the middle of the test range. Multiply the value by the dilution factor to determine the concentration of the substance in the undiluted water. NOTE: Diluting the sample also may be helpful when using drop-count titration method (e.g., hardness test) when you expect the concentration will be high. By diluting one part sample with one part DI water, the number of drops required will be cut in half. Counting is simplified and less chemical is required.

The dilution factor is the sum of the parts of deionized water added to one part of the sample water. For example, if 3/4 cup (3 parts) of deionized water is added to 1/4 cup (1 part) of sample, the dilution factor is four.

Chlorine

Two types of tests are available, free chlorine and total chlorine. Use the free chlorine test to determine chlorine residual after a retention or contact tank. Use the total chlorine test to determine the effectiveness of treatment for free chlorine and chloramine removal. To determine the chloramine level, perform both tests and the following calculation:

Chloramines = Total Chlorine – Free Chlorine

Hydrogen Sulfide (see Hydrogen Sulfide section in Chapter 3)

Methane

For methane, use the "Flash Test".

1. Fill a plastic bottle with the water, leaving about one inch of air space above the water. Cap the bottle tightly.
2. Shake the bottle vigorously or allow it to come to room temperature.
3. Light a match, remove the cap, and place the flame close to the bottle opening.
4. Observe the flame.
   a. If there is a pop or a flare, the gas likely is methane.
   b. If the flame goes out, the gas likely is carbon dioxide.
   c. If the flame burns normally, the gas likely is air.

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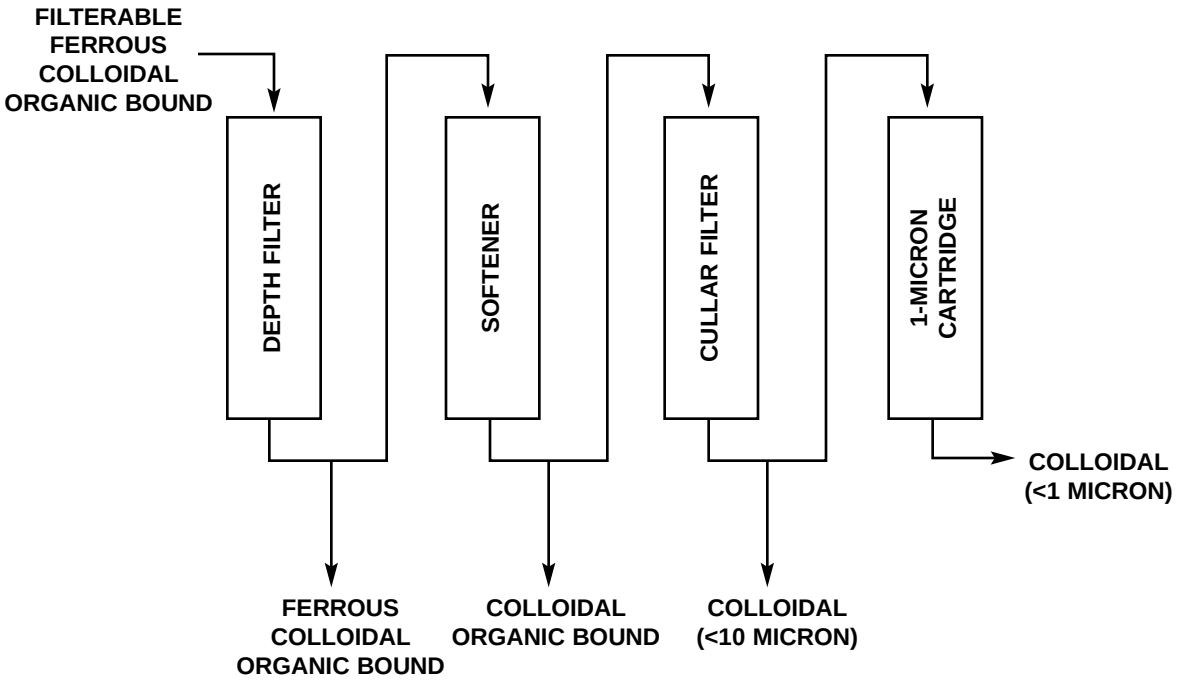
Iron

The best way to determine the type(s) of iron present is in the field using a series of "demo" cartridges you prepare at your dealership. Start with an empty Flavr-Gard™ cartridge, Cat. No. 00-9552-63 and add media as indicated below. If you do not have used Flavr-Gard housings, ordering a complete filter, Cat. No. 00-4450-63, will cost less than ordering a head and bowl.



The demo depth filter contains 4" (10 cm) of Cullsan® U filter medium below 4" (10 cm) of Cullsan G-50 filter medium. A 10-micron cartridge filter could be used in place of the demo depth filter, but small air bubbles in the cartridge will oxidize some of the ferrous iron, affecting the accuracy of the test. As indicated in the diagram, a demo depth filter removes only filterable iron (particles of rust larger than 10 microns).

The demo softener contains 0.033 cubic feet of Cullex® resin. It will remove ferrous iron, but not bound or colloidal iron. Because of the small volume of resin, exhausted resin should be replaced with new resin rather than be regenerated.

The demo activated carbon filter is filled with 0.033 cubic feet (about 7/8 pound) of Cullar® D media, the recommended activated carbon for organics removal. A carbon cartridge filter could be substituted, but the carbon in these cartridges is intended primarily for chlorine removal, not organics removal. If you use macroporous anion resin for organics removal, substitute this resin for the Cullar D media. This filter removes organic bound iron.

Iron that passes through the first three filters is particulate iron smaller than 10 microns. According to field reports, in many applications these small particles of rust are larger than 1 micron. Therefore, if iron passes through the first three housings, add a fourth housing with a 1-micron cartridge to determine if it will remove the remaining iron. If so, a Plymouth Products model DGD-2501 cartridge with Big Blue housing would be recommended.

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Testing

The filter housings should be connected with flexible tubing and quick-disconnect fittings. Since the system will be operated at line pressure, the demo depth filter inlet tubing should use a garden hose connector for attachment to a laundry tub faucet or outside hose bib. The flow rate for testing should be 0.25 – 0.5 gpm. Use the top of a household brine valve with a 0.45 gpm flow control for a convenient method of controlling the flow.

To start, test the raw water for iron. Particulate iron may take some time to dissolve, so the color may get deeper with time. Wait about 5 minutes for the color to stabilize. In the meantime, connect the demo depth filter inlet to the raw water and the flow control to the outlet. Turn on the water, relieve air from the filter housing, and allow the water to flow for five minutes. Take a sample after the filter and test for iron. If iron is present, connect the softener after the depth filter and connect the flow control after the softener. Test the water after the demo softener for hardness to verify that the softener is working. If you get a hardness bleed through the softener, you also will get an iron bleed, and the test will not be valid. Test the soft water for iron. If iron is present, continue testing with the carbon filter and, if iron still is present, with the 1 micron cartridge filter.

Now compare the results of the iron tests to determine the type(s) of iron present. For example:

Raw:	5.0 mg/L
After depth filter	4.5 mg/L (removed 0.5 mg/L filterable iron)
After softener:	2.5 mg/L (removed 2.0 mg/L ferrous iron)
After Cullar filter:	1.0 mg/L (removed 1.5 mg/L organic bound iron)
After 1 micron filter	0.2 mg/L (removed 0.8 mg/L filterable iron)

The 0.2 mg/L of iron that passed through all three units is likely to be colloidal, which will require coagulation for removal. It could also be polyphosphate bound iron if the water is a municipal supply treated with polyphosphate (contact the water treatment plant operator). Please note that the iron level is below the U.S. EPA secondary drinking water standard of 0.3 mg/L, so further treatment may not be needed.

Corrosion Testing

If we suspect that copper or iron in water is due to corrosion of plumbing, we want to sample the water that is resting in the pipes. The standard procedure of letting the water flow before taking a sample will flush the corrosion products down the drain, so the testing procedure for corrosion requires a modified procedure:

1. Turn on the water and allow only a cup of water to flow to drain before taking a sample. If possible, sample from the fixture where staining is occurring. Test this sample for copper (blue-green stains) or iron (rust stains).
2. Turn on the water and let the water flow to drain for two minutes. Take another sample and test again.
3. If the first sample has a higher copper or iron level than the second sample, corrosion is occurring. Test for pH, carbon dioxide, and bicarbonate, and look for sources of oxygen (air).
4. If the copper or iron level is essentially the same in both samples, the copper or iron is coming from the water supply, not corrosion.

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Solids

Sometimes a water treatment problem involves a solid material causing plugging, turbidity, or staining. In many cases, field testing of the solid can provide a rough identification of the material.

First, identify the color of the material. Next, determine its density by putting in water. Does it sink rapidly, stay in suspension, or float? NOTE: If the material dissolves in water, it is a sodium scale remaining after water evaporated.

Prepare an acid test solution by adding one part of hydrochloric (muriatic) acid to two parts of deionized water in a plastic container. WARNING: Observe all handling precautions for hydrochloric acid. Even after dilution, the acid solution still is considered strong. Label the container and keep it tightly closed when not in use.

Add the solid material to the acid solution and observe what happens. If the solid material cannot be separated from the water, add one part acid to two parts of the water sample. Look at the table below to see if the material's properties match one of the listed compounds.

Color	Dissolves and Fizzes	Dissolves with Odor	Dissolves	Does Not Dissolve, Sinks	Does Not Dissolve, Floats
White	Hardness Scale			Sand, Calcium Sulfate	Organics
Brown	Hardness Scale with Iron		Rust	Sand	Organics
Black		Metallic Sulfide	Manganese Dioxide	Carbon	Carbon Fines, Organics
Blue-Green	Hardness Scale with Copper		Copper		

If you cannot identify the material by field testing, collect at least a teaspoon of the material in a container and send it to the water analysis laboratory at Northbrook. NOTE: If a paper towel or filter cartridge containing the material is used, the lab may not be able to separate the material for analysis.

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Testing

Jar Testing

Jar testing is used to determine coagulant dosage. Coagulants are used when solid particles in water are too small to be removed by conventional filtration. Examples include alum, F-86 polymer, and F-88 polymer.

Materials Required: Coagulant chemicals

- Alum ($Al_2(SO_4)_3.18H_20$) or Potassium alum ($KAl(SO_4)_2.12H_20$)
- F-86 polyelectrolyte
- F-88 polyelectrolyte (for low turbidity water)
- Soda ash (Na_2CO_3) – only required with alum

Hardware

- Clean 5-gallon bucket
- Large measuring cup, 1-pint or 1-quart size (0.5 or 1 liter)
- Weighing scale capable of measuring in ounces (dry) or grams
- Clean covered glass or plastic containers for storing the chemical solutions
- 100-ml graduated cylinder
- Four or five glass containers ("jars") capable of holding at least 100 ml of sample. Although any container will do, laboratory-type flasks or beakers will present a more professional appearance.
- Glass or plastic stirring rod (about the length and diameter of a drinking straw)
- Medicine dropper
- Plastic funnel (PN 00-4900-21)
- Whatman #1 filter paper (PN 00-4900-20)
- pH test paper or kit – only required with alum feed

Solution Preparation: Prepare 2000 ppm (mg/L) solutions of the following chemicals. One drop of each solution added to 100 ml of sample represents 1 ppm (mg/L) dosage.

Alum Using the measuring cup, add 3.75 gallons (14.175 Liters) of RO or DI water to the bucket. NOTE: 2 cups = 1 pint, 2 pints = 1 quart, and 4 quarts = 1 gallon. Weigh out one dry ounce (28.35 g) of alum, add it to the water and stir. Fill a storage container with this solution and discard any remaining solution. Mark the container, "Alum Jar Test Solution".

Soda Ash Follow the same procedure as for alum, except use soda ash and mark the container "Soda Ash Jar Test Solution". NOTE: Do not use light soda ash or washing soda to prepare this solution. Also, this solution loses strength quickly and should be prepared within a day of performing the jar tests.

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F-86 Chemical Using the measuring cup, add 1.5 gallons (5.8 Liters) of RO or DI water to the bucket. Using the graduated cylinder, measure out 10 ml of F-86 chemical, add it to the water, and stir. Fill a storage container with this solution and discard any remaining solution. Mark the container "F-86 Jar Test Solution".

F-88 Chemical Follow the same procedure as for F-86 chemical, except use F-88 and mark the container "F-88 Jar Test Solution".

Test Procedure:

1. Add 100 ml of the sample to be tested to all but one of the jars.
2. Using the medicine dropper, add varying amounts of coagulant to each jar. For example, add one drop of F-86 solution to jar #1, two drops to jar #2, etc. Typical F-86 chemical dosage is 1-5 ppm, while typical alum dosage is 10-30 ppm (15-45 ppm for potassium alum).
3. Stir the samples gently with the stirring rod. Rapid stirring may prevent coagulation.
4. Alum only - Alum is an acid and may lower the pH to the point where coagulation does not occur. The optimum pH range for alum coagulation is 7.2 - 7.5. Measure the pH of the samples after alum addition and add soda ash solution drop-wise until the pH of the sample is in the optimum range. Stir the samples gently with the stirring rod.
5. Fold the Whatman filter paper into a cone and place it in the funnel. Place the funnel into the extra jar. Pour the solution from jar #1 into the funnel and allow the solution to flow through the filter paper. You do not have to filter all 100 ml of sample, just enough so that you can compare sample clarity with the other samples.
6. Discard any remaining solution from jar #1 and discard the filter paper from the funnel. Rinse both thoroughly with clean water. This container now is the "extra" jar.
7. Repeat steps 5 and 6 for the remaining samples. Be sure to note which jar contains which dosage of coagulant.
8. Compare each sample for remaining cloudiness in a well-lit area using a contrasting background (e.g., a dark background for viewing white cloudiness). The sample with the least cloudiness has the optimum coagulant dosage.

If the sample with the lowest or highest coagulant dosage has the least cloudiness, but still is cloudy, repeat the jar testing with a lower or high coagulant dosage, respectively. For example, if the sample with 1 ppm coagulant is the clearest but still is cloudy, try a 0.5 ppm dosage. For dosages less than 1 ppm, use more sample (200 ml means each drop is 0.5 ppm) or dilute the coagulant solution with RO or DI water (one part coagulant solution with 3 parts water means each drop is 0.25 ppm).

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Chapter 5

Chapter 5

Products

Introduction

Culligan International Company offers a broad array of products to treat problem water:

Softeners	Neutralizers	Reverse osmosis systems
Chloride Anion Resin Units	Carbon filters	Ultraviolet systems
Deionizers	Particulate filters	
Carboxylic resin units	Oxidizing filters	

The above systems are listed in this chapter in the order shown above. In addition, aeration systems and Cul-Cleer™ systems also are described.

Softeners

Process

Water softeners remove hardness by ion exchange. As noted in Chapter 3, hardness can be described as any ion with a +2 charge. A softener includes a media tank containing Cullex® cation exchange resin. This resin consists of plastic beads with millions of cation exchange sites. Each exchange site can be thought of as a negative "magnet" that attracts positive ions, or cations.

Service Cycle. In the service cycle, the resin exchange sites are occupied by sodium ions (Na^{+1}). As water passes down through the resin, the sodium ions are knocked off the resin and replaced by hardness ions. The sodium ions go to service, while the hardness ions remain on the resin. Eventually, the ion exchange sites are filled with hardness ions, using up the resin's capacity for hardness, and the resin must be regenerated.

Regeneration. The first step of regeneration is backwash. Although some particulates may be flushed to drain during backwash, the primary purpose of backwash is to "fluff up" the resin to prepare it for the next step, brine draw. A concentrated solution of brine (sodium chloride, NaCl) is drawn into the tank. The brine is mixed with water, about one part brine with two parts water. The brine solution passes through the resin bed. Although hardness ions are attracted to the resin more strongly than sodium ions, the high concentration of the brine knocks off the hardness ions and replaces them with sodium ions. The hardness ions are flushed to drain with the brine, and the sodium ions remain on the resin. Note that the chloride ions in the brine solution do not participate in any of these reactions, so all the chloride ions go to drain. After all the brine has been drawn into the tank, it is slowly rinsed from the tank with water. The last cycle is fast rinse, which compacts the resin bed and rinses out any remaining brine.

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Capacity. The amount of hardness that the resin can remove is called its capacity, and it depends on the amount of salt used for regeneration. The following table shows approximate hardness capacities at various salt dosages per cubic foot of cation resin:

Salt Dosage (lbs)	Capacity (grains)*	Capacity per Pound*
6	20,000	3333
10	25,000	2500
15	30,000	2000

*** Actual capacity will vary with water temperature, analysis and flow rates**

A higher salt dosage results in a higher capacity because it knocks off more hardness, especially from the lower portion of the resin bed. When there is less hardness remaining on the resin at the bottom of the resin bed, there is less chance that this hardness will pass ("leak") to service. On the other hand, a lower salt dosage is more efficient, since it removes more hardness per pound of salt.

Components

An automatic softener consists of three main components, a media tank, a control valve, and a brine system.

Media Tank. The media tank contains Cullex cation exchange resin in varying amounts depending on the size of the tank. It may also contain Cullsan underbedding media at the bottom to assist in distributing water at the bottom of the tank. Water enters the top of tank through an inlet manifold, which distributes the water over the top of the resin. The softened water is collected at the bottom of the tank by an outlet manifold, then rises up the outlet manifold tube and out of the tank.

Control Valve. The control valve directs the flow of water through the tank during the service and regeneration cycles. A motor moves an internal piston to open and close ports inside the valve. During backwash, a flow control limits the flow to drain and prevents resin from lifting out of the tank. During brine draw, water flows through a venturi, or eductor, to create a vacuum and draw brine into the tank. The flow to drain during fast rinse is limited by the same flow control that limits the backwash flow rate.

The control valve also contains a timer that determines the time and frequency of regeneration, as well as the amount of salt used for regeneration. There are three methods to control the frequency of regeneration:

1. **Timeclock.** With this method, the timer is set to regenerate the softener every day, every other day, every third day, etc., based on the water hardness and the average daily water usage. Information on calculating the regeneration frequency setting is in the softener installation and operating instructions. Note that the softener will regenerate at this frequency no matter how much or how little water is used.

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2. **Soft-Minder® meter.** With this method, a meter on the outlet side of the control measures the amount of water that has been softened. After a pre-determined number of gallons has been softened, the meter signals that a regeneration is needed. For softeners with a single media tank, regeneration is delayed until a time of no water usage (e.g., 2:00 AM) so that softened water is available throughout the day. To ensure adequate softening after the signal is sent, a reserve capacity is required. Information on calculating the gallons settings is in the softener installation and operating instructions. Because the softener regenerates based on the number of gallons treated rather than time, there is a potential for significant savings on salt and water.

   ***NOTE**: In order to realize salt savings, the reserve capacity should be no more than 1/3 of the total capacity.*

3. **Aqua-Sensor® Sensing Device.** With this method, a probe is installed in the media tank. The probe contains two cells that are immersed in the resin, an upper sensing cell and a lower reference cell, which continuously monitor the condition of the surrounding resin. When the upper cell is in exhausted resin, the lower cell is still in fresh resin, and an electrical imbalance occurs. This imbalance sends a signal to the timer indicating that regeneration is needed. For softeners with a single media tank, regeneration is delayed until a time of no water usage (e.g., 2:00 AM) so that softened water is available throughout the day. To ensure adequate softening after the signal is sent, a reserve capacity is required. This reserve is set automatically by the position of the sensing cell in the resin. Since the Aqua-Sensor Sensing Device measures the actual state of the resin, it compensates not only for changes in water usage, but also for changes in water hardness.

Control valves are available for inlet/outlet pipe sizes from 3/4 inch to 1-1/4 inch. Larger valves can handle a higher flow rate for a given pressure drop, or provide a lower pressure drop for a given flow rate. The table shows approximate values for flow at a 15 psi pressure drop for complete softener systems with bypass. More precise values are available in the softener literature.

Series	Pipe Size(in)	Approx. Flow (gpm)	Approx. Cv
Platinum	1-1/4	15	3.9
Gold	1	10	2.6
Medallist	3/4	7.6	1.9

The approximate pressure drop at a particular flow rate can be calculated using the Cv factor from the table:

$$\text{Pressure drop} = (\text{Flow rate}/Cv)^2$$

For example, the approximate pressure drop through a Platinum Series softener at 7.5 gpm would be $(7.5/4.83)^2 = 2.4$ psi. Compared to a 3/4-inch valve, the 1-1/4 inch valve has a much lower pressure drop at normal residential flow rates.

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Brine System. A brine system consists of a plastic tank with cover, and a brine valve inside a tube (brine valve chamber) that separates the brine valve from salt. When the softener enters the brine draw cycle, brine is drawn from the bottom of the brine valve to the control valve and into the media tank. When all the brine has been drawn from the tank, an air eliminator ball in the brine valve drops onto a seat to prevent air from being drawn into the media tank. At the end of the regeneration cycle, the control valve sends soft water back to the brine tank through the brine valve. The top of the brine valve contains a flow restrictor to control the flow of water into the brine tank. Each gallon of water returned to the brine tank will dissolve three pounds of salt. Thus, a precise salt dosage is determined by controlling the refill time at a fixed refill flow rate.

Application

Proper application of a softener ensures that it will be able to remove hardness between regenerations without excessive hardness bleed, and that the softener will continue to function reliably.

Hardness. The industry standard for soft water is water that contains less than 1 gpg of hardness. The higher the hardness level of the hard water, the more difficult it will be to keep the hardness level low in the conditioned water. Each softener model has a maximum hardness limit, based on the amount of Cullex resin in the media tank. This does not mean that the softener cannot be applied on water with a higher hardness level, but it indicates that the hardness level of the softened water may be higher than 1 gpg. No matter what the hardness level, a higher salt dosage will minimize the amount of hardness to service.

Sodium. In most water supplies, the hardness level is higher than the sodium level. When the sodium level is higher than the hardness level, there may be a significant hardness bleed. In addition, a high sodium level will make it more difficult for an Aqua-Sensor Sensing Device to detect the difference between exhausted and fresh resin. As with high hardness, a higher salt dosage will minimize the amount of hardness to service.

Iron and Manganese. Clear water iron (Fe^{+2}) and soluble manganese (Mn^{+2}) can be removed by ion exchange softening, just like other hardness ions. However, when exposed to oxygen or other oxidizing agents, the iron on the resin can convert to rust. Over time, the resin will become fouled.

Note: *Manganese fouling is very rare, except in the Northeast. If manganese fouling in known to occur in your area, add the values for iron and manganese together to determine the total fouling potential.*

Two guidelines are used to predict the potential for resin fouling. First, the clear water iron level should not exceed 5 mg/L. The second guideline is called the "8 to 1 Hardness to Iron Ratio". Divide the hardness level, in grains per gallon, by the clear water iron level, in parts per million. Example: 20 gpg hardness divided by 3 mg/L iron gives a ratio of 6.7. If the result is less than eight, as in the example, iron fouling is likely.

Note: *A ratio below eight does not mean the softener will not be able to remove all the clear water iron. It means only that the resin likely will become fouled.*

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A number of methods are used to prevent iron fouling.

1. If the ratio of hardness to iron is greater than 8, and the iron level is less than 5 mg/L, the softener can be regenerated more often. This will prevent iron from accumulating in the bottom of the resin bed, where it is the most difficult to remove. Calculate the compensated hardness:
   a. Multiply the iron level by 0.1.
   b. Add the result from Step a to the total hardness.
   c. Determine the percent of the resin capacity you want to use, then determine the multiplier from the table.

% Capacity	50	67	75
Multiplier	2	1.5	1.33

   d. Multiply the result of Step b by the multiplier. The result is the compensated hardness. Use this value for sizing and programming the softener.

      Example: The total hardness is 20 gpg, the iron level is 2 mg/L, and 67% of the capacity will be used. The result for Step b is 20.2 gpg. The multiplier is 1.5, so the compensated hardness is 30.3 gpg.
2. If the ratio of hardness to iron is less than 8, and the iron level is less than 5 mg/L, use a commercially available acid- or bisulfite-based resin cleaner with the salt. If the softener will regenerate at least every other day, this can be as simple as mixing Ironeater™ chemical with the salt.

   Note: *Ironeater solution loses strength after a few days. When using this method, also use the compensated hardness as shown in Method 1.*
3. If the iron level is greater than 5 mg/L, use a Sofner-Gard® (Ironeater™) chemical feed system. Although it has a mild ability to clean resin, the primary purpose of Ironeater chemical is to remove oxygen from the brine. In the absence of oxygen, clear water iron on the resin will not be oxidized to rust, and will regenerate off the resin like other hardness ions. When using this method, the 8 to 1 ratio does not apply, and the compensated hardness calculation is not required. There is no specific iron limit, but the higher the clear water iron level, the more likely there will be an iron bleed to service. The Sofner-Gard Accessory chemical system is available for softeners containing up to 1.5 cubic feet of resin. See the appendices for information on a chemical feeder system applicable to all softeners.

Suspended Solids. A softener should not be used to remove suspended solids. Particulates in water can plug screens and eductor nozzles in a softener control valve, preventing eduction of brine during regeneration. The softener backwash flow rate is limited to prevent loss of resin, so heavier particles will remain in the media tank. If suspended solids are present, they should be removed by a centrifugal separator, depth filter, or large cartridge filter installed ahead of the softener.

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Products

Chlorine. Free chlorine can degrade ion exchange resin. When new, Cullex® resin is dark brown to black, and the spherical plastic beads are relatively hard. Over time, exposure to chlorine will cause the resin to turn a light amber color. At this point, the resin capacity will not be significantly affected. With further exposure, however, the capacity will decrease and the resin will become mushy. The chlorine limit for Cullex resin is 1 mg/L. With no chlorine, resin can last twenty years or more. For each 1 mg/L of free chlorine, the estimated life would be cut roughly in half (10 years @ 1 mg/L, 5 years @ 2 mg/L, etc.). To prevent resin degradation by chlorine, install an activated carbon filter ahead of the softener.

Reserve Capacity. Softeners with a single media tank and a control operating with a meter or Aqua-Sensor Sensing Device may send a regeneration signal at the beginning of the day. However, the regeneration will not occur until the end of the day. To ensure soft water is available for the rest of the day, a reserve capacity is required. If there is not enough reserve capacity, the resin will become exhausted and hard water will go to service. The softener installation and operating instructions show the calculations for determining reserve capacity for metered units. For units using the Aqua-Sensor Sensing Device:

1. Subtract the capacity to signal from the total capacity. This is the reserve capacity.
2. Divide the reserve capacity by the total hardness level. This is the gallons of reserve capacity.
3. Compare the gallons of reserve capacity to the anticipated daily water usage. If the reserve capacity is less than the daily water usage, a larger salt dosage or softener will be required.

Flow Rate. The industry standard for flow rate is the flow at which there is a 15 psi drop in pressure from the inlet to outlet of the unit. Capacity specifications are validated at this flow rate. Although the hardness leakage will be less than 1 gpg, it will be lower at lower flow rates. This can be important when using a softener to remove clear water iron, since any hardness leakage will be accompanied by iron leakage.

On the other hand, there may be times when the flow rate is too low. At a low flow, the water will not be distributed throughout the resin bed. It will follow a path, or channel, through part of the resin bed. As a result of this channeling, that part of the resin through which the water is flowing will become exhausted, and hardness will go to service. To prevent channeling, the minimum recommended flow rate is 2 gpm per square foot of bed area (see table).
Note: *Short periods of low flow will not result in hardness bleed.*

Diameter, in	8	9	10	12	16	24	30	36	42
Bed Area, Sq. Ft.	0.35	0.44	0.55	0.79	1.4	3.1	4.9	7.1	9.6
Minimum Flow, gpm	0.7	0.9	1.1	1.6	2.8	6.2	10	14	20

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Chloride Anion Resin Systems

Chloride Anion Resin (CAR) systems are similar to softeners, except they contain anion resin instead of Cullex® cation resin.

Process

CAR systems remove various anions by ion exchange. Depending on the specific anion resin, the anions removed include bicarbonate and sulfate, nitrate, or dissolved organic material. A system includes a media tank containing a specific anion exchange resin. This resin consists of plastic beads with millions of anion exchange sites. Each exchange site can be thought of as a positive "magnet" that attracts negative ions, or anions.

There are three types of resins commonly used in CAR systems:

1. CS-2, Strong Base Anion, Type II resin. This resin is used for removal of bicarbonate and sulfate in a dealkalizer (CAR-D)system. This resin should not be used for nitrate removal. Sulfate ions entering the media bed will knock nitrate ions off the resin and send them to service. The result would be a higher nitrate level in the treated water than in the untreated water.

2. SR-7 and A-520E Nitrate specific resins. As the name implies, these resins are intended for nitrate removal (CAR-N system). They will not cause higher levels of nitrate in the treated water.

3. MacroT or CS-5 Macroporous resin. Also known as tannin resins or organic scavenger resins, these resins are intended to remove dissolved organic material like tannins (CAR-O system).

Service Cycle. In the service cycle, the resin exchange sites are occupied by chloride ions (Cl^{-1}). As water passes down through the resin, the chloride ions are knocked off the resin and replaced by anions. The chloride ions go to service, while the anions remain on the resin. Eventually, the ion exchange sites are filled with anions, using up the resin's capacity, and the resin must be regenerated.

Regeneration. The first step of regeneration is backwash. Although some particulates may be flushed to drain during backwash, the primary purpose of backwash is to "fluff up" the resin to prepare it for the next step, brine draw. A concentrated solution of brine (sodium chloride, NaCl) is drawn into the tank. The brine is mixed with water, about one part brine with two parts water. The brine solution passes through the resin bed. Although the anions on the resin are attracted to the resin more strongly than chloride ions, the high concentration of the brine knocks off the anions and replaces them with chloride ions. The anions are flushed to drain with the brine, and the chloride ions remain on the resin. Note that the sodium ions in the brine solution do not participate in any of these reactions, so all the sodium ions go to drain. After all the brine has been drawn into the tank, it is slowly rinsed from the tank with water. The last cycle is fast rinse, which compacts the resin bed and rinses out any remaining brine.

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Capacity. The capacity of anion resin depends on the type of application.

CAR-D (Dealkalizer) Systems. For dealkalizer applications, a complete water analysis is recommended. You will need to know the following values:

		Example
Total Hardness (gpg)	_____	20
Total Alkalinity (mg/L)	_____	200
Chloride (mg/L as $CaCO_3$)	_____	140
Sulfate (mg/L as $CaCO_3$)	_____	50
TDS (mg/L)	_____	400
pH	_____	7.4

1. If the hardness is above 10 gpg, a softener should be installed ahead of the dealkalizer.
2. Add the Total Alkalinity, Chloride, and Sulfate values to obtain the Total Anion level. (200 + 140 + 50 = 390 mg/L)
3. Divide the Total Alkalinity by the Total Anion value, then multiply by 100 to obtain the % Alkalinity value. (200/390 = 0.51 x 100 = 51%)
4. Refer to the table to determine the capacity per cubic foot of resin.

% Alkalinity	Capacity, grains @ 250 mg/L TDS	Capacity, grains @ 500 mg/L TDS
20	1500	2000
30	2500	3500
40	3500	4500
50	4000	5500
60	5500	6500
70	6500	7500
80	8000	9000
90	9500	10,000
100	10,500	11,500

Culligan "Chlevide Anion Deallalizer Selection Worksheet", PN 8177-14 (Rev. 12/88) based on the paper "Dealkalization" by M. Keller and S. Zarkowski (Sylvana Chemicals)

(50 % alkalinity, 400 TDS indicates a capacity of about 5000 grains per cubic foot).

NOTE: *The equation for capacity is* ***Capacity = 114 x %Alkalinity + ((2 xTDS) - 1280)****, where %Alkalinity is a whole number (e.g., 50% is 50), and TDS is the Total Dissolved Solids in mg/L.*

5. Reduce the capacity by 10% (multiply by 0.9) as a safety factor. (5000 x 0.9 = 4500 grains)
6. Convert the Total Alkalinity level to grains per gallon by dividing by 17.1. (200/17.1 = 11.7 gpg)
7. Calculate the gallons treated between regenerations by dividing the capacity by the Total Alkalinity. (4500 grains / 11.7 gpg = 385 gallons per cubic foot)

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8. Determine the daily water usage. (400 gallons per day)
9. Calculate the minimum amount of resin required to treat the daily water usage.

   Minimum resin volume (cubic feet) = $\frac{\text{Daily water usage (gallons)}}{\text{Gallons per cubic foot}}$

   (minimum resin volume = 400/385 = 1.04 cubic feet)

10. Calculate the bicarbonate leakage, which will be about 10% of the incoming bicarbonate level. (0.1 x 200 = 20 mg/L bicarbonate leakage)

CAR-N (Nitrate specific) Systems. To apply SR-7 or A-520E resin, you must know the nitrate and sulfate levels in mg/L as calcium carbonate (CaCO3). Culligan water analyses report nitrate both as N (Nitrogen) and as calcium carbonate. Sulfate reported as the element and as calcium carbonate. If you are using a field test or independent lab report where nitrate is not expressed, you must convert the values.

If nitrate is reported as N, multiply by 3.57
If nitrate is reported as NO3, multiply by 0.81
If sulfate is reported as SO4, multiply by 1.04

Next, calculate the % nitrate factor, which is used to determine nitrate capacity.

$$\%\ NO_3 = \frac{NO_3}{NO_3 + SO_4},$$ all in mg/L as $CaCO_3$

Then refer to the appropriate table below to determine the capacity in grains per cubic foot.

SR-7 Capacity (grains/cu.ft.)

Salt Dosage (lbs/cu.ft.)	$\%NO_3 = 100$	$\%NO_3 = 75$	$\%NO_3 = 50$	$\%NO_3 = 30$	$\%NO_3 = 20$	$\%NO_3 = 10$
10	9800	7700	5800	4200	3200	2300
15	11,000	8800	6700	5100	4100	3300
20	12,100	9800	7200	5600	4600	3800

The last step is to determine the leakage, since not all the nitrate will be removed in most applications. Any nitrate remaining must be below the drinking water standard.

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SR-7 Leakage (as % of influent NO_3)

Salt Dosage (lbs/cu.ft.)	$\%NO_3$ = 100	$\%NO_3$ = 75	$\%NO_3$ = 50	$\%NO_3$ = 30	$\%NO_3$ = 20	$\%NO_3$ = 10
10	12	19	27	35	40	45
15	4	9	15	20	24	28
20	0	3	7	10	13	16

Example: Nitrate = 15 mg/L as N, Sulfate = 50 mg/L as sulfate, 7 gpm service flow rate, 400 gallons per day water usage, SR-7 resin.

Since the service flow rate rating is up to 5 gpm per cubic foot, we will need 1.4 cubic feet of resin.

Nitrate - 15 mg/L as N x 3.57 = 53.55 mg/L as $CaCO_3$

Sulfate - 50 mg/L as SO_4 x 1.04 = 52 mg/L as $CaCO_3$

$$\% \text{ Nitrate} = \frac{53.55}{53.55 + 52} = 0.507 \ (50.7\%)$$

Use the 50% column for the calculations.

At 10 lbs./cu.ft., Dosage is (10 x 1.4) or 14 pounds
Capacity is (5800 x 1.4) or 8120 grains
Leakage is (0.27 x 15 =) 4.05 mg/L as N

At 15 lbs./cu.ft. Dosage is (15 x 1.4) or 21 pounds
Capacity is (6700 x 1.4) or 9300 grains
Leakage is (0.15 x 15 =) 2.25 mg/L as N

At 20 lbs./cu.ft. Dosage is (20 x 1.4) or 28 pounds
Capacity is (7200 x 1.4) or 10,800 grains
Leakage is (0.07 x 15 =) 1.05 mg/L as N

To convert mg/L of nitrate as $CaCO_3$ to gpg of nitrate, divide by 17.1. Therefore, the nitrate level in this example is (53.55/17.1 =) 3.13 gpg of nitrate as $CaCO_3$.

If a 15 lbs./cu.ft. salt dosage is chosen, the gallons treated between regenerations is (9300 grains/3.13 gpg =) 2971 gallons. The water usage is 400 gpd, so the regeneration frequency is (2971 gallons/400 gpd =) 7.4 days. Regenerate at least once every 7 days, or more often if there are days when more than 400 gallons used.

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CAR-O (organic scavenger) Systems. Macroporous anion resins do not have a specific capacity specification. Rather, regeneration frequency must be set for at least every third day, with every-other-day regeneration preferred. This will prevent dissolved organic material from migrating toward the center of the resin beads, where it is difficult to remove from the resin during regeneration. The salt dosage should be set at 10 pounds per cubic foot of resin.

Components

Media Tank. Identical to softener media tank, except CAR-N and CAR-O systems use a fine-slot inlet manifold to prevent loss of resin during backwash.

Control. Identical to softener control, except CAR-D systems use the next-smaller eductor and backwash flow control. For example, a CA-12 dealkalizer uses flow controls from a 9-inch softener.

Brine System. Identical to softener brine system.

Application

Specifications. Review the following table for information on pretreatment requirements, service flow rate ratings, and salt dosages.

Specification	CS-2	SR-7	A-520E	MacroT	CS-5
Hardness, max. (gpg)	10	10	10	10	10
Iron, max. (mg/L)	0.1	0.1	0.1	0.1	0.1
Turbidity, max. (NTU)	5	5	5	1	5
Chlorine, max. (mg/L)	0.05	0.5	0.05	1	0.1
T.O.C., max (mg/L)	3	3	3	NA	NA
Service Flow, max.* (gpm/sq.ft. bed area)	5	10	8	10	5
Salt dosage, lb/cu.ft.	5	Varies	Varies	10	10

*Assumes 24-30 inch bed depth

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Mixed bed softeners. A popular field modification is substituting macroporous anion resin for some of the Cullex resin in a softener. A typical system will contain 0.5 cubic foot of anion resin and 1.0 cubic fot of Cullex resin. The resins are not really mixed, since the lighter anion resin will be above the cation resin. The result is a system that can remove both dissolved organic material and hardness. Although many of these applications have been successful, there is a potential problem. During regeneration, calcium is removed from the Cullex resin, and both bicarbonate and sulfate are removed from the anion resin. If the raw water exceeds the hardness limit of 10 gpg, there may be enough calcium to combine with bicarbonate or sulfate and precipitate in the outlet manifold, control valve, and drain line.

pH change. As with the reverse osmosis process, CAR systems will remove bicarbonate alkalinity but allow dissolved carbon dioxide to pass to service. The result is that the treated water usually will have a lower pH than the untreated water. The corrosivity of the water has not changed because the carbon dioxide level has not increased, but some customers may be concerned about the lower pH. The pH change can be minimized by adding about one pound of soda ash for every 40-50 bag of salt added to the brine tank. However, when adding soda ash, the hardness limit decreases to 0 gpg, and the brine cannot be used to regenerate softening resin.

Fishy odor. New anion resin in the chloride form sometimes produces a fishy odor in the treated water. The odor will decrease each time the new resin is regenerated. The resin should be regenerated prior to placing the system in service.

Nitrate monitoring. Unlike reverse osmosis or deionizer systems, a conductivity or resistivity meter cannot be used to monitor CAR-N system performance. A nitrate test kit should be provided to the customer along with a demonstration on how to use the kit. The untreated water should be tested because a change in the influent level of nitrate will affect the number of gallons the system can treat between regenerations. The treated water should be tested to ensure the nitrate level is below the drinking water standard.

Notice: *Modification of an ANSI, WQA or UL certified system voids that certification. If non-Culligan parts or materials are used for replacement on a certified system, the system is no longer certified. Either case requires that the certification dataplate be removed from the system.*

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Deionizers

Process

Service Cycle and Regeneration. Deionizers use the same cation resin as softeners and anion resins similar to CAR systems, but they do not regenerate with salt.

The cation resin is regenerated with hydrochloric acid or sulfuric acid, and is said to be in the hydrogen form. As water passes through the resin, cations are removed and replaced with hydrogen ions (H^{+1}). The anion resin is regenerated with caustic, sodium hydroxide, and is said to be in the hydroxide form. As water passes through this resin, anions are removed and replaced with hydroxide ions (OH^{-1}). The hydrogen ions combine with the hydroxide ions to form water (HOH, or H_2O).

There are three basic types of deionizers, which differ in the type of anion resin used whether or not the resins are mixed:

1. A two-bed, weak base system consists of a cation resin tank followed by a weak base anion tank. Weak base anion resin can remove sulfate and bicarbonate, but not carbon dioxide or silica. Typical water from this system has a resistivity of 50,000 ohms, about 10 mg/L.
2. A two-bed strong base system consists of a cation resin tank followed by a strong base anion tank. Strong base anion resin removes carbon dioxide and silica, in addition to the anions that can be removed by weak base anion resin. Typical water from this system has a resistivity of 200,000 ohms, about 2.5 mg/L.
3. A mixed-bed system consists of a single tank containing both cation resin and strong base anion resin. The resins are thoroughly mixed, so each cation/anion resin bead pair acts like an miniature two-bed strong base deionizer. The result is a very high quality water, with a resistivity exceeding 1,000,000 ohms (1 Megohm), and a TDS below 0.5 mg/L

Capacity. The table below shows nominal capacities and flow rates for a variety of portable exchange deionizers. Actual capacities may be considerably different, depending on the influent water quality. Due to the complexity of the capacity calculations, use the Computer Aided Application Program (CAAP®) software for these calculations.

Specification	D-25P	D-45P	9-inch	12-inch
Capacity, Cation, grains	-	-	45,000	75,000
Capacity, Weak Base, grains	-	-	45,000	75,000
Capacity, Strong Base, grains	-	-	30,000	50,000
Capacity, Mixed Bed, grains	2500	4500	12,500	20,000
Flow Rate Range, Weak Base, gpm	-	-	1-5	2-8
Flow Rate Range, Strong Base, gpm	-	-	1-5	2-8
Flow Rate Range, Mixed Bed, gpm	0.15-0.8	0.25-0.8	1-5	2-8

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Products

Components

Some deionizer systems include controls and solution tanks to regenerate on-site. However, these systems required handling and disposal of acid and caustic chemicals, so residential applications use only portable exchange media tanks that are regenerated off-site.

Application

Deionizers have been replaced almost completely by reverse osmosis systems in residential applications. They should be considered when reverse osmosis alone is not able to reduce a dissolved ion level to an acceptable limit.

A softener *should not* pre-treat two-bed systems. The high sodium level in the softened water will cause a sodium bleed from the cation tank. The sodium will not be able to neutralize the caustic from the anion tank, so the treated water will have a high pH.

A softener *should be* used to pre-treat mixed-bed systems. Hardness in the anion resin may cause resin fouling.

A carbon filter should be used to remove chlorine, which will damage anion resin quickly.

Carboxylic Systems

Process

Service Cycle and Regeneration. Weak-acid cation resin is used in carboxylic systems. As water passes through the resin, alkalinity (bicarbonate, carbonate, or hydroxide) removes hydrogen ions (H^{+1}) from the resin. The resin then attracts and holds hardness ions. The hydrogen ions react with the alkalinity to produce carbon dioxide or water. When the resin is exhausted, it is regenerated with acid.

Capacity. The resin capacity will vary, depending on the water hardness and alkalinity. Due to the complexity of the capacity calculations, use the Computer Aided Application Program (CAAP®) software for these calculations.

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Components

As with deionizers, residential applications use only portable exchange media tanks that are regenerated off-site.

Application

Carboxylic systems have limited applications, but one popular one is for icemakers. If the hardness level is at least 80% of the alkalinity level, the hardness ions will be removed and replaced by hydrogen ions, which will combine with the alkalinity to produce carbon dioxide or water. The result is not only lower hardness, but also lower TDS. The carbon dioxide can gas off in the icemaker. The net result is clearer ice cubes without requiring a reverse osmosis or deionization system, and reduced maintenance for the icemaker.

Neutralizers

Process

Neutralizers are intended to reduce corrosion by raising the pH level and decreasing the carbon dioxide level. There are two types of neutralizing media, Cullneu® (calcium carbonate, CaCO3) and Cullneu C (magnesium oxide, MgO). They react with carbon dioxide to produce calcium or magnesium ions, plus bicarbonate ions.

$$CaCO_3 + CO_2 + H_2O = Ca^{+2} + 2HCO_3^{-1}$$
$$MgO + 2CO_2 + H_2O = Mg^{+2} + 2HCO_3^{-1}$$

The media are known as "sacrificial" because they slowly dissolve as they react with the carbon dioxide.

Service. With standard neutralizers, water flows down through the media. In some applications, the water can flow down the outlet manifold to the bottom of the tank, then up through the media and out to service. This flow pattern eliminates the need for a control, but it requires a cartridge filter after the neutralizer tank to remove fine particles of media.

Regeneration. The first regeneration cycle is backwash. Water flows down the outlet manifold to the bottom of the tank, up through the media, and out to drain. Backwashing removes fine particles from the media. The next step is a pause, followed by a fast rinse step (downflow) to compact the media in preparation for service.

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Products

Capacity. In theory, one pound of Cullneu media can neutralize about 26,000 grains of carbon dioxide, while one pound of Cullneu C media can neutralize about 130,000 grains of carbon dioxide (CO_2 as $CaCO_3$). In practice, the amount neutralized will be less, since the rate of dissolving depends on a number of factors:

1. Contact time. The longer the contact time, the more carbon dioxide will be neutralized. The contact time decreases with increasing flow rate.
2. Langlier Saturation Index. The LSI is a calculated value indicating whether calcium carbonate will precipitate (positive LSI) or dissolve (negative LSI). The lower the LSI, the more carbon dioxide will be neutralized. If the LSI is positive, Cullneu will not be able to neutralize carbon dioxide.
3. Temperature. The higher the temperature, the more carbon dioxide will be neutralized (as long as the LSI is negative).

Components

A manual or automatic Cullneu neutralizer consists of two main components, a media tank and a control valve. Portable exchange neutralizers use only the media tank.

Media Tank. The media tank contains Cullneu® media in varying amounts depending on the size of the tank. Water enters the top of tank through an inlet manifold, which distributes the water over the top of the media. The treated water is collected at the bottom of the tank by an outlet manifold, then rises up the outlet manifold tube and out of the tank.

Control Valve. The control valve directs the flow of water through the tank during the service and regeneration cycles. For automatic controls, a motor moves an internal piston to open and close ports inside the valve. For manual controls, turning a knob moves the piston. During backwash, a flow control limits the flow to drain and prevents media from lifting out of the tank. The flow to drain during fast rinse is limited by the same flow control that limits the backwash flow rate.

The automatic control valve also contains a timer that determines the time and frequency of regeneration.

Product Specifications

Unit	Service Flow (gpm)	Media (cu. ft.)
9" Culligan Gold Series™	4.0	1.1
10" Culligan Gold Series™	6.0	1.6
8" Culligan Medallist Series™	2.7	1.0
10" Culligan Medallist Series™	4.0	1.5
9" Portable Exchange	4.0	1.5

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Application

Variable neutralization. Due primarily to changes in flow rate, the pH increase and carbon dioxide decrease after a neutralizer will vary. After sitting overnight, the pH of the treated water may be 9.0 or higher. On the other hand, when flowing at a rate of 4 gpm, the pH increase may be less than 0.5 unit.

pH guideline. In the past, a pH guideline was used to determine whether to use Cullneu media alone, or with Cullneu C media:

(old guidelines) pH 6-7 – use Cullneu media
pH 5-6 – use Cullneu and Cullneu C media
pH below 5 – use a chemical feeder

The old guidelines did not account for the level of carbon dioxide, which does not correspond directly with pH. To remove all of the carbon dioxide, the pH would have to be raised above 8.3, which is not possible with Cullneu media alone. To ensure a minimum level of carbon dioxide, consider using a Cullneu/Cullneu C media mixture when the pH is below 7. Since Cullneu C media dissolves relatively easily, it can solidify if used alone. To prevent this problem, mix one part of Cullneu® C with 5 parts of Cullneu media. Regardless of the media loading, the carbon dioxide level after the neutralizer should be tested to verify it has been reduced below 2 gpg (34 mg/L).

Hardness added. As Cullneu media dissolves, hardness is added, so the neutralizer should be installed ahead of a softener. For softener sizing, figure one grain per gallon of hardness will be added for every grain per gallon of carbon dioxide.

Activated Carbon Filters

Process

Activated carbon is made from a variety of high carbon content materials, including wood, coconut shell, coal, and petroleum. The activation process typically includes heating and reacting with sulfuric acid to create a highly porous material. The activated carbon may be left as a powder or combined with a binder to form Granular Activated Carbon (GAC) or a carbon block.

Because activated carbon is porous, it has a large surface area available to adsorb a wide variety of contaminants, including free chlorine, chloramines, volatile organic chemicals (VOC's), and dissolved organic materials like tannins. In the process of adsorption, contaminants are weakly attracted to and held at the surface of the carbon. In general, the less water-soluble the contaminant, the greater the attraction.

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Removal of free chlorine also involves oxidation. After adsorption, the chlorine reacts with the carbon to produce carbon fines (small particles of activated carbon), chloride, and carbon dioxide. The carbon fines are sent to drain during backwash. Although the carbon does break down over time, the net result is a very high capacity for free chlorine removal.

The size of the pores in the carbon often determines the type(s) of contaminants most readily removed. A variety of Cullar® GAC media are available:

Cullar CC is made from coconut shells and has a high percentage of small pores. This media is intended for removal of hydrogen peroxide and VOC's.

Cullar D is made from lignite coal and has a high percentage of large pores. This media is intended for removal of high molecular weight dissolved organic material like tannins.

Cullar D Plus is made from bituminous coal and has a broad range of pore sizes. Although this media can remove a variety of contaminants, it is specifically intended for reduction of chlorine and chloramines. It is the standard carbon included with automatic, manual, and portable exchange Cullar filters.

Cullar F is made from bituminous coal and has a large particle size. It is intended for use as underbedding for portable exchange softeners, enabling a single tank to remove both hardness and low levels of free chlorine. NOTE: The free chlorine level should not exceed 1 mg/L, the limit for softener resin. Over time the Cullar® F media will break down into fines, so it should not be used with automatic softeners.

Cullar G is made from bituminous coal and is very hard, making it suitable for use in cartridges. It also is the recommended carbon for detergent and oil removal.

Cullar M is made from bituminous coal and is treated with acid to remove trace amounts of copper and aluminum. It is specifically intended for free chlorine and chloramine removal in medical applications.

Service and Regeneration (automatic and manual units). Water flows down through the activated carbon and contaminants are removed. The media requires regeneration when contaminants are detected in the treated water or when the pressure drop from inlet to outlet increases by 10 psi. The first regeneration cycle is backwash. Water flows down the outlet manifold to the bottom of the tank, up through the media, and out to drain. Backwashing removes fine particles from the media. The next step is a pause, followed by a fast rinse step (downflow) to compact the media in preparation for service.

Capacity. A variety of factors make it practically impossible to predict the capacity of activated carbon:

1. Activated carbon can adsorb a wide variety of organic materials. Each contaminant is attracted more or less strongly than the others, so a contaminant that is strongly attracted can knock off a contaminant that is weakly attracted.
2. Contact time between the water and the carbon can vary widely with service flow rate. The longer the contact time, the higher the capacity.
3. The pH of the water may affect the form of the contaminant. In general, activated carbon is more effective at a lower pH level.

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Components

A manual or automatic Cullar filter consists of two main components, a media tank and a control valve. Portable exchange filters use only the media tank. In addition to tank-type units, there are also a wide variety of cartridge filters containing powdered, granular, or block carbon.

Media Tank. The media tank contains Cullar D Plus media in varying amounts depending on the size of the tank. Water enters the top of tank through an inlet manifold, which distributes the water over the top of the media. The treated water is collected at the bottom of the tank by an outlet manifold, then rises up the outlet manifold tube and out of the tank.

Control Valve. The control valve directs the flow of water through the tank during the service and regeneration cycles. For automatic controls, a motor moves an internal piston to open and close ports inside the valve. For manual controls, turning a knob moves the piston. During backwash, a flow control limits the flow to drain and prevents media from lifting out of the tank. The flow to drain during fast rinse is limited by the same flow control that limits the backwash flow rate.

The automatic control valve also contains a timer that determines the time and frequency of regeneration.

Product Specifications

Unit	Service Flow (gpm)	Media (cu. ft.)
9" Culligan Gold Series™	4.0	0.75
10" Culligan Gold Series™	6.0	1.0
8" Culligan Medallist Series™	4.0	0.75
10" Culligan Medallist Series™	4.0	1.0
9" Portable Exchange	4.0	1.5

Application

Flow Rate. There are three criteria for estimating the proper service flow rate.

1. Free chlorine removal typically calls for a maximum service flow rate of 10 gpm per square foot of bed area.
2. Chloramine and dissolved organic material removal typically calls for a service flow rate of 5 gpm per square foot of bed area.
3. Contaminant removal in critical applications (chloramine removal for fish, V.O.C. removal to satisfy U.S. EPA Maximum Contaminant Levels) call for an Empty Bed Contact Time of 6-10 minutes. These applications require two tanks in series, with each tank containing half the required carbon.

NOTE: *Although channeling (flow through only part of the media bed) can occur, it generally does not cause a problem due to increased contact time with the media. Continuous channeling will cause early exhaustion of the media, but backwashing will redistribute the media to restore most of the remaining capacity.*

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Empty Bed Contact Time (EBCT). Because activated carbon is so porous, the solid carbon occupies only a small percent of its total volume. The majority of the volume is empty. Therefore, when calculating how long the water is in contact with the carbon, the carbon volume is approximated as empty. The following equation is used to calculate EBCT:

$$\text{EBCT (minutes)} = \frac{\text{Volume of Carbon (cu.ft.)} \times 7.45}{\text{Flow Rate (gpm)}}$$

For example, if the volume of carbon is 0.75 cu. ft. and the flow rate is 4 gpm,

$$\text{EBCT} = \frac{0.75 \times 7.45}{4} = 1.4 \text{ minutes}$$

If the desired empty bed contact time is known, the volume of carbon required can be calculated:

$$\text{Volume (cu.ft.)} = \frac{\text{EBCT (minutes)} \times \text{Flow Rate (gpm)}}{7.45}$$

For example, if the EBCT is 10 minutes and the flow rate is 7 gpm,

$$\text{Volume (cu.ft.)} = \frac{10 \times 7}{7.45} = 9.4 \text{ cu.ft.}$$

NOTE: *If an EBCT of 7.45 minutes is chosen, the required volume of carbon in cubic feet is the same as the flow rate in gpm (5 gpm would require 5 cubic feet of carbon).*

pH Change. Some carbons contain low residuals of acid or caustic chemicals used in activating the carbon. As a result, the pH of the treated water may be lower or higher than the untreated water. This effect will be most noticeable when the influent water has an bicarbonate alkalinity level below 100 mg/L, since such waters have low buffering capability. In most cases, the pH of the treated water will become the same as the untreated water with a few days.

V.O.C. Reduction. As noted above, reduction of Volatile Organic Chemicals requires a relatively large volume of carbon, split between two tanks in series. Sampling valves are required before, between, and after the tanks:

1. Before, to monitor changes in influent V.O.C. levels
2. Between, to determine when it is time to change the carbon
3. After, to verify successful removal of contaminant(s).

Responsibility for monitoring should be determined prior to the sale of the system, since monitoring can involve substantial costs.

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When the carbon in the first tank is exhausted, remove the tank and replace with the second tank. Place a tank with fresh carbon in the second (polishing) position. Since the exhausted carbon probably will be considered hazardous waste, a licensed waste hauler should be contacted to determine local costs and requirements for disposal.

Microbial Growth. Activated carbon is not intended for reduction of microorganisms. However, many of the substances removed by activated carbon can act as nutrients for microorganisms. Removal of free chlorine and chloramines will allow their growth. Therefore, some applications may experience problems with microbial growth in the media. There are a number of methods to minimize the problem:

1. Sanitize the empty tank with bleach prior to loading the media. Empty excess bleach from the tank, but do not rinse the tank with water.
2. Keep the carbon dry until it is loaded into the tank.
3. Cap the inlet and outlet fittings until a control is assembled onto the tank.
4. Caustic soda can be used to sanitize the carbon at the dealership, although it will take a long time to rinse from the carbon. If using caustic soda, the pH of the solution should be at least 2 pH units higher than the pH of the water normally entering the tank.
5. If the untreated water contains "nuisance" microorganisms (e.g., iron bacteria) and varying levels of chlorine, install a needle valve between the untreated and treated water piping. Adjust the needle valve to allow a low level (0.2-0.5 mg/L) of chlorine to go to service. This will not prevent biogrowth in the tank, but it will minimize any problems downstream.

Note: *If the water contains harmful bacteria, an activated carbon filter should not be used.*

Placement. If free chlorine is present, an activated carbon filter should be installed before a softener to extend the life of the Cullex® resin, which has a maximum chlorine limit of 1 mg/L. In most other applications, an activated carbon filter should be installed after any other filters and the softener.

Particulate Filters

As the name implies, a particulate filter is intended to remove particles, also called suspended solids, from water. There are a wide variety of products to remove suspended solids, including centrifugal (cyclone) separators, Filtr-Cleer® depth filters, particulate cartridge filters, and even carbon block cartridge filters.

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Products

Process

Centrifugal Separator. A cyclone separator is designed for removal of relatively dense particles like sand. Dense particles will settle from water in about 1 minute. As water enters the separator, the water flow is directed into a spinning (cyclonic) motion. Dense particles collect at the center and drop to the bottom of the separator. The treated water exits the top of the separator.

Depth Filter. A depth filter contains a number of specially selected media to remove particles throughout the depth of the media. A Filtr-Cleer depth filter contains the media shown in the table.

Media	Material	Filtration
Cullcite®	Anthracite Coal	Coarse
Cullsan® A	Flint	Medium
Cullsan G-50	Garnet	Fine (10 micron)
Cullsan U	Granite	(underbedding)

Service and Regeneration (automatic and manual depth filters). Water flows down through the Cullsan® media and particles are removed. The coarse particles are removed in the upper Cullcite® media layer, while the finest particles (as small as 10 microns in diameter) are removed in the lower Cullsan G-50 media layer. The media requires regeneration when particles are detected in the treated water or when the pressure drop from inlet to outlet increases by 10 psi. The first regeneration cycle is backwash. Water flows down the outlet manifold to the bottom of the tank, up through the media, and out to drain. Backwashing removes the accumulated solids from the media. The next step is a pause, followed by a fast rinse step (downflow) to compact the media in preparation for service.

Capacity. The capacity of a particulate filter will depend on the sizes of the particles as well as their concentration. As an approximation, a depth filter can remove approximately 9.5 pounds of suspended solids per square foot of bed area between regenerations, based on a service flow rate of 7 gpm/sq.ft. and a backwash rate of 12 gpm/sq.ft. This capacity translates to the capacities in the following table.

Tank Diameter(in)	Capacity(ppm-gal)	Service Flow(gpm)(Lpm)	Backwash Flow (gpm)
8	400,000	2.4 (9.0)	4
9	500,000	3 (11.4)	5
10	625,000	3.8 (14.4)	7
12	900,000	6 (22.7)	9
16	1,600,000	10 (38)	17
20	2,500,000	15 (57)	25

The approximate number of gallons filtered between backwashes is the capacity divided by the suspended solids concentration. For example, if a 9-inch Filtr-Cleer® depth filter is applied on a water supply containing 64 mg/L of suspended solids, the gallons treated would be approximately (500,000/64 =) 7800 gallons.

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Components

A manual or automatic Filtr-Cleer depth filter consists of two main components, a media tank and a control valve. Portable exchange filters use only the media tank..

Media Tank. Water enters the top of tank through an inlet manifold, which distributes the water over the top of the media. The treated water is collected at the bottom of the tank by an outlet manifold, then rises up the outlet manifold tube and out of the tank.

Control Valve. The control valve directs the flow of water through the tank during the service and regeneration cycles. For automatic controls, a motor moves an internal piston to open and close ports inside the valve. For manual controls, turning a knob moves the piston. During backwash, a flow control limits the flow to drain and prevents media from lifting out of the tank. The flow to drain during fast rinse is limited by the same flow control that limits the backwash flow rate.

The automatic control valve also contains a timer that determines the time and frequency of regeneration.

Cartridges. There are many types of cartridges available for particulate removal, including pleated sheet, string wound, cast, and membrane. All are available in a variety of micron removal ratings. In general, cast polypropylene cartridges are recommended for whole-house particulate removal. In particular, a model DGD-2501 cartridge has proven very effective at removing particles as small as 1-micron while still retaining a high capacity. Membrane cartridges are expensive, but are recommended where absolute micron filtration is needed, e.g., for a sub-micron air vent.

Product Specifications

Unit	Service Flow (gpm)	Backwash Flow (gpm)
9" Culligan Gold Series™	9.0	4.5
10" Culligan Gold Series™	12.0	7.0
8" Culligan Medallist Series™	7.8	4.5
10" Culligan Medallist Series™	9.0	7.0
9" Portable Exchange	9.0	N/A

Note: *The specified service flow rates are considerably higher than the service flow rates listed in the capacity table. Although the filters can operate at the higher flows for short periods of time, continuous operation at the higher flows will decrease the effective capacity and increase the amount of small suspended solids going to service.*

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Application

Well pump flow rate. Backwashing is the only way to remove suspended solids from a depth filter, so there must be enough flow available. Centrifugal separators are installed between the well pump and the pressure tank, and sized based on the well pump flow rate. See the appendix for information on checking the well pump flow rate.

Water temperature. The backwash flow rates are based on a water temperature range of 50-60°F. If the water is very cold, the media bed may expand too much and some of the upper layer, Cullcite®, may be lost to drain. On the other hand, if the water is warm (above 70°F), the media bed may not expand enough to allow removal of all the suspended solids. Change to a smaller flow control for cold water, or a larger flow control for warm water.

Regeneration frequency. The table above can be used to determine regeneration frequency. However, surface water supplies commonly contain a significant amount of organic material that may "cement" together over time. Also, iron freshly oxidized in water is soft, but can crystallize into harder particles over time. Therefore, if a water supply contains a Total Organic Carbon or freshly oxidized iron level over 3 mg/L, the depth filter should regenerate at least every three days. If the filter is not backwashed frequently enough and cementation occurs, the entire bed may be lifted up during backwash (bed positioning), resulting in a major loss of media to drain.

Duplex systems. In the table showing capacities and flow rates, note that the backwash flow rate is approximately twice the service flow rate. If the filter is large enough to handle the peak flow rate, it is too large for the water supply to provide an adequate backwash flow rate. In many applications, the best solution is to use two depth filters in parallel, and stagger the times of regeneration.

Sand. A depth filter should not be used to remove sand, which is too dense to be backwashed from the filter. As noted above, the recommended treatment is a centrifugal (cyclone) separator. When the sand particles are large and occur only occasionally, an alternative treatment is a reverse-flow tank, which typically is a portable exchange tank with the lower 1/3 of the outlet manifold cut off. Water enters the tank through the outlet manifold, rises from the bottom of tank, and exits through the inlet manifold. As the water rises, the heavy sand sinks to the bottom of the tank. The sand is dumped from the tank when it reaches the end of the outlet manifold or when it is noticed going to service.

Cysts. Because cysts are resistant to chlorination, the most common treatment for these microorganisms is filtration. However, cysts are typically 3-5 microns in size and thus are too small to be removed by depth filtration. A cartridge filter should be used for cyst reduction. Be sure to choose a cartridge system that is third-party certified for cyst reduction. Examples of such systems include the Preferred Series filters (150, 250, and 350), the Model US-640 filter, and the SY-2000,SY -2300, and SY–2500 cartridge systems.

NOTE: *Some reverse osmosis drinking water systems also are certified for cyst reduction.*

NOTE: *The water must be disinfected prior to entering the cartridge system for the certification to be valid.*

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Oxidizing Filters

Oxidizing filters use an oxidizing chemical (oxidizing agent) to react with certain contaminants. Although more commonly known as iron filters, oxidizing filters also are applied for removal of hydrogen sulfide. Some oxidizing filters also can remove moderate amounts of manganese. Culligan® International offers Cullsorb® filters, Super S™ filters, and Iron-Cleer™ filters.

NOTE: *If none of the iron in the water supply is clear water iron, a different type of filter should be used because there is no iron to oxidize. Oxidized iron (rust) should be removed by a depth or cartridge filter, while organic-bound iron should be removed by a Cullar® activated carbon filter or a macroporous anion resin (CAR-O) system.*

Process

Iron. Iron removal is a two-step process:

1. Clear water iron + oxidizing agent = oxidized iron

2. Oxidized iron + alkalinity = rust + acid

Alkalinity is used up when the oxidized iron precipitates. Each mg/L of iron that precipitates consumes 3.6 mg/L of alkalinity. In addition, acid is produced by the precipitation. The net result is a decrease in the alkalinity and the pH of the water. At lower pH levels, the oxidation reaction slows down or even stops. Therefore, the water must have enough alkalinity to precipitate the iron and to neutralize the acid. The minimum recommended alkalinity level for iron oxidation is 100 mg/L.

On the other hand, a high pH will speed up the oxidation reaction. When the reaction occurs too quickly, there may not be enough time to form large, filterable particles of rust, and the result is colloidal iron. The ideal pH range for iron oxidation is 7.2-7.5, although the filters will work adequately over a pH range of 7.0-7.7.

The following table shows the recommended maximum service flow rates, based on an industry standard of 5 gpm per square foot of bed area. If the pH of the untreated water is below 7.0, the service flow rate should be lower to account for the slower reaction.

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Tank Diameter(in)	Service Flow (gpm)(Lpm)
9	2.2 (8.3)
10	2.7(10)
12	3.9 (15)
16	7.0 (26)
20	11 (41)
24	16 (59)
30	24 (93)
36	35 (133)
42	48 (182)
48	63 (237)
54	79 (300)
60	98 (370)

Hydrogen sulfide. Hydrogen sulfide (H_2S) removal is a single step process, but there are two possible reactions:

1. Hydrogen sulfide + oxidizing agent = sulfate (SO_4^{-2})

2. Hydrogen sulfide + oxidizing agent = elemental sulfur (S_8)

The first reaction is desirable since the sulfate remains in solution and passes to service. Each mg/L of hydrogen sulfide will produce about 3 mg/L of sulfate, so the resulting water may exceed the secondary MCL for sulfate.

The second reaction definitely is not desirable. Elemental sulfur is a milky-yellow, fine, sticky powder. It has plugged media, manifold screens, control valves, and piping. It is inert and cannot be dissolved by cleaning chemicals. Although formation of elemental sulfur cannot be predicted with accuracy, it appears to be favored by a high pH and the presence of elemental sulfur in the untreated water. If it occurs, the formation of elemental sulfur can be reduced by feeding acid to lower the pH to at least 7.0, and by installing a large cartridge filter ahead of the oxidizing filter to reduce the elemental sulfur.

Manganese. The oxidation of manganese is slow unless the pH is high, usually over 9. However, if a manganese dioxide media (Cullsorb® media or birm) is used, the media can adsorb the soluble manganese. With a continuous feed of oxidizing agent (potassium permanganate or oxygen), the adsorbed manganese can be oxidized to manganese dioxide. The oxidizing filter systems using this process are continuous-feed Cullsorb filters and Iron-Cleer™ filters. The Cullsorb filter has maximum influent limit of 10mg/L of iron plus manganese, while the Iron-Cleer filter has a maximum influent manganese limit of 0.5 mg/L.

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Oxidizing Agent. The following table shows the dosage of chemical required for the various oxidizing filter for removal of iron, manganese, or hydrogen sulfide.

Oxidizing Filter	Oxidizing Chemical	Mg/L Chemical per mg/L Iron	Mg/L Chemical per mg/L Manganese	Mg/L Chemical per mg/L Hydrogen Sulfide
Cullsorb® (batch)	Manganese Dioxide	—	—	—
Cullsorb (cont. feed)	Potassium Permanganate	0.94	1.9	12.4
Super S®	Oxygen	0.14	—	1.88
Super S	Chlorine	—	—	8.3
Iron-Cleer™	Oxygen	0.14	0.29	1.88

Note that the level of oxidizing agent required for hydrogen sulfide removal is about 13 times higher than the level required for clear water iron removal. This fact emphasizes the importance of measuring the hydrogen sulfide level and ensuring that there is an adequate level of oxidizing agent at all times. If there is not adequate oxidizing agent, not only will hydrogen sulfide pass to service, but also Cullsorb media and Iron-Cleer media will become stripped of their manganese dioxide coating and become permanently damaged. Also, these media will send soluble manganese to service.

Service and Regeneration. Although all iron filters operate with the same basic principals, each uses a different oxidizing agent and/or regeneration method.

Batch Cullsorb filters operate very much like softeners. Water flows down through the Cullsorb media, where the manganese dioxide coating oxidizes clear water iron and/or hydrogen sulfide and the rust is removed. The soluble manganese is retained on the media. The first regeneration cycle is backwash. Water flows down the outlet manifold to the bottom of the tank, up through the media, and out to drain. Backwash is the only cycle that removes the accumulated rust from the media. The next cycle is solution draw, during which potassium permanganate is drawn into the media tank. The permanganate oxidizes the soluble manganese on the media back to manganese dioxide. After all the chemical solution has been drawn into the tank, it is slowly rinsed from the tank with water. The last cycle is fast rinse, which compacts the Cullsorb media bed and rinses out any remaining chemical.

Continuous feed Cullsorb filters, used primarily in commercial applications, have a potassium permanganate solution fed continuously ahead of the filter tank. Clear water iron, hydrogen sulfide, and soluble manganese are oxidized, and precipitated material is removed by the filter. The regeneration cycle is identical to that for a depth filter.

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Products

Super S® filters use an air compressor, which activates periodically to inject air into the media tank. The Culligan Iron Media (CIM) holds oxygen from the air in the filter media. The oxygen reacts with clear water iron and hydrogen sulfide, and the filter removes precipitated material. The regeneration cycle is identical to that for a softener, except chlorine bleach is educted into the tank rather than brine.

Iron-Cleer™ filters also use an air compressor, but the air is injected into an aerator tank installed ahead of the filter tank. The aerator tank provides extra contact between the air and the water, and extra time for the reactions to occur. The birm media in the filter tank completes the reactions, while the Cullsan® G-50 media below the birm filters out particles as small as 10 microns. The regeneration cycle is identical to that for a depth filter.

Capacity. Rated capacities for iron are shown in the following table.

Oxidizing Filter	Capacity (ppm-gal)
Cullsorb, 9"(batch)	6000
Cullsorb (cont. feed)	N/A
Super S	10,000
Iron-Cleer, 10"	15,000
Iron-Cleer, 12”	20,000

Cullsorb filter (batch). These filters require special calculations because the media causes the oxidation, rather than oxygen or other oxidizing agent. Multiply the hydrogen sulfide level by two, then add the iron level. For example, if the hydrogen sulfide level is 2 mg/L and the clear water iron level is three mg/L, the total load on the filter would be ((2 x 2) +3) = 7 mg/L. The maximum total load limit is 10 mg/L. To determine the number of gallons treated between regenerations, divide the capacity by the total load. For example, if the total load is 7 mg/L, the gallons treated by a 9" Cullsorb filter would be (6,000/7) = 857 gallons. NOTE: If the water contains clear water iron, the filter should backwash at least every 3 days to prevent the freshly precipitated iron from crystallizing on the media.

Cullsorb filter (continuous feed). Since this system oxidizes iron and manganese ahead of the filter tank, the filter is acting primarily as a depth filter, and the capacity for the system would be the same as for a depth filter, based on the loading of the clear water iron plus oxidized iron.

Super S filter and Iron-Cleer filter. To determine the number of gallons treated between regenerations, divide the capacity by the iron level. For example, if the total iron is 7 mg/L, the gallons treated by a 10" Iron-Cleer filter would be (15,000/7) = 2143 gallons. NOTE: If the water contains clear water iron, the filter should backwash at least every 3 days to prevent the freshly precipitated iron from crystallizing on the media.

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Components

Cullsorb® (batch) filters are available in automatic or manual operation, while the other filters use automatic operation only. All filters consist of two main components, a media tank and a control valve. Iron-Cleer™ filters also use an aerator tank ahead of the filter tank.

Media Tank. For Iron-Cleer filters only, water enters the top of the aerator tank through an inlet manifold, which sprays the water through a pocket of air in the top of the tank. The aerated water is collected at the bottom of the tank by an outlet tube, where it rises to the top of the tank and goes to the media tank.

Water enters the top of media tank through an inlet manifold, which distributes the water over the top of the media. The treated water is collected at the bottom of the tank by an outlet manifold, then rises up the outlet manifold tube and out of the tank.

Control Valve. The control valve directs the flow of water through the tank during the service and regeneration cycles. For automatic controls, a motor moves an internal piston to open and close ports inside the valve. For manual controls, turning a knob moves the piston. During backwash, a flow control limits the flow to drain and prevents media from lifting out of the tank. The flow to drain during fast rinse is limited by the same flow control that limits the backwash flow rate.

The automatic control valve also contains a timer that determines the time and frequency of regeneration.

Control valves for Super S® filters and Iron-Cleer filters also include an air compressor, which is activated by an adjustable ON/OFF cycling relay. The on and off times are set according to the levels of contaminants. Compressor cycles are independent of regeneration.

Product Specifications

Unit	Service Flow (gpm)	Backwash Flow (gpm)
9" Cullsorb filter	6.2	5.0
Super S filter	5	5.5
10" Iron-Cleer filter, 0.75"	4	5.5
10" Iron-Cleer filter, 1"	5.0	5.5
12" Iron-Cleer filter	7.0	8.0

Although the filters can operate at the higher flows for short periods of time, continuous operation at the higher flows will increase the possibility of iron passing to service.

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Application

Well pump flow rate. Backwashing is the only way to remove precipitated iron from an oxidizing filter, so there must be enough flow available. See the appendix for information on checking the well pump flow rate.

Water temperature. The backwash flow rates are based on a water temperature range of 50-60°F. If the water is very cold, the media bed may expand too much and some of the media may be lost to drain. On the other hand, is the water is warm (above 70°F), the media bed may not expand enough to allow removal of all the suspended solids. Change to a smaller flow control for cold water, or a larger flow control for warm water.

Application order. In most applications, an oxidizing filter would be installed after a depth filter, but ahead of a cartridge filter, softener, and carbon filter. There are two applications where the oxidizing filter would be installed after a softener:

1. The iron level, or the iron level plus the hydrogen sulfide level, is over the limit for the oxidizing filter. The softener can be used to remove the clear water iron, so the oxidizing filter only has to remove the hydrogen sulfide.

2. The hardness level or the TDS level is so high that there would be a hardness bleed through the softener. If there is a hardness bleed, there will be a clear water iron bleed. The oxidizing filter then could remove the clear water iron that came through the softener.

NOTE: *When an oxidizing filter is installed after a softener, there will be nothing to remove soluble manganese that may bleed from the media. For this reason, a Super S® filter, which uses media that does not contain manganese, is recommended for these applications.*

REVERSE OSMOSIS SYSTEMS

A reverse osmosis system is intended primarily to reduce the Total Dissolved Solids (TDS) level of the water. Since TDS is commonly measured by conductivity, and conductivity is a function of dissolved ions, the TDS reduction is primarily the reduction of dissolved ions.

Culligan International Company offers a variety of reverse osmosis systems, including Good Water Machines™ for drinking water, and Series B and Series A systems for whole-house treatment.

Process

Osmosis is a naturally occurring process involving the passage of water through a semi-permeable membrane from a region of low ionic concentration to a region of high ionic concentration. A semi-permeable membrane is a natural or synthetic organic membrane that allows passage of certain substances (water), but restricts passage of others (ions). An example of osmosis occurs when gargling with salt water to relieve sore throat pain. Water travels from the swollen throat cells through the semi-permeable cell membrane into the high TDS water, reducing the swelling and reducing the pain.

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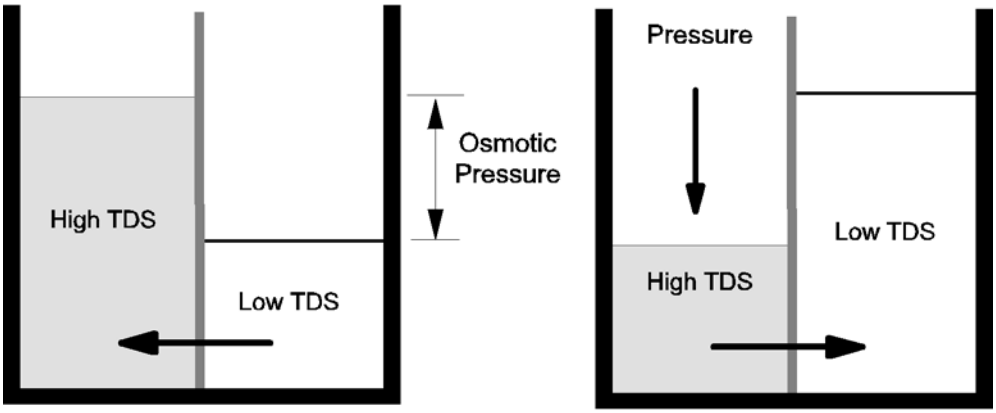
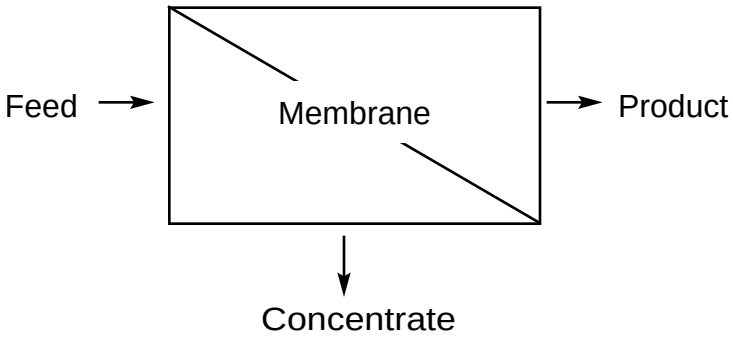
If a semi-permeable membrane in a container separates two water solutions with different TDS levels, the water will pass through the membrane from the low TDS side to the high TDS side. The water level on the high TDS side will rise until the weight of the extra water pushes back enough to prevent flow through the membrane. This weight represents the osmotic pressure, which is proportional to the difference between the TDS levels of the two water solutions.



If pressure higher than the osmotic pressure is applied to the water on the high TDS side, the flow of water will be reversed. Since water can pass through the membrane more easily than dissolved ions, the water coming through the membrane has a substantially reduced TDS level.

As the reverse osmosis process pushes low TDS water through the membrane, the TDS level in the remaining water increases. Eventually, the TDS level can become high enough to stop the process or to cause dissolved ions to precipitate. To prevent these problems, fresh water is introduced into the container and the very high TDS water is sent to drain.

The fresh water entering the reverse osmosis system is called "Feed" water, the low TDS water coming from the system is called "Product" water, and the high TDS water going to drain is called "Concentrate" water.



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Calculations. The two performance criteria for the reverse osmosis process are quality and quantity.

Quality is expressed in terms of "% Rejection", which indicates the reduction in TDS level in the product water relative to the TDS of the feed water. It is calculated as follows:

$$\% \text{ Rejection} = \frac{\text{TDS (feed)} - \text{TDS (product)}}{\text{TDS (feed)}} \times 100$$

For example, if the TDS of the feed water is 500 mg/L and the TDS of the product water is 17 mg/L,

$$\% \text{ Rejection} = \frac{500 - 17}{500} \times 100$$

$$= 96.6\%$$

Another expression for quality is "% Salt Passage", which is simply 100 minus the percent rejection. Using the above example, the salt passage is 3.4%.

Quantity is expressed in terms of gallons of product water produced per day. A number of factors affect product flow, including temperature, pressure and TDS.

a. Temperature. The colder the water, the lower is the product flow. In a sense, the colder water is "thicker" and does not pass through the membrane as easily. Temperature correction factors (TCF's) are used to estimate the change in water flow relative to the standard temperature, which is a relatively warm 77°F. Tables of the factors are available in the installation and operating instructions, but the following table is adequate for estimating:

Temperature, °F	TCF
77	1.0
55	1.5
40	2.0

To estimate the product flow at a lower temperature, divide the standard flow by the TCF. For example, if the standard flow is 30 gallons per day (gpd), the flow at 55°F would be (30/1.5 =) 20 gpd.

b. Pressure. The product flow is directly proportional to pressure driving water through the membrane.. There are three components affecting pressure.

1. **Water pressure.** This is the pressure seen on a pressure gauge. Depending on the specific system, standard pressure could vary from 50 psi for drinking water systems up to 225 psi for commercial systems.

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2. **TDS.** The higher the TDS of the feed water, the higher is the osmotic pressure that must be overcome to drive water through the membrane. The standard TDS is 500 mg/L. If the feed TDS is above the standard TDS, the osmotic backpressure is approximately 1 psi for every 100 mg/L over the standard TDS. For example, if the feed TDS is 1400 mg/L, the osmotic backpressure is ((1400-500)/100 =) 9 psi.

3. **Product pressure.** If the product water is stored in a pressure tank, the pressure in the storage tank will push backward against the feed pressure.

The pressure pushing water through the membrane is the Net Driving Pressure (NDP)

NDP = Water pressure – osmotic backpressure – product pressure

For example, if the water pressure is 60 psi, the TDS is 1400 mg/L, and the product pressure is 20 psi, the NDP is (60-9-20 =) 31 psi.

Once the NDP is calculated, it can be used to determine a Pressure Correction Factor (PCF), similar to the Temperature Correction Factor (TCF).

$$PCF = \frac{\text{Net Driving Pressure}}{\text{Standard Pressure}}$$

For example, if the NDP is 31 psi and the standard pressure is 50 psi, the PCF is (31/50 =) 0.62.

To determine flow at the NDP, multiply the standard flow by the PCF. Using the example, the flow of a 30 gpd system would be (30 x 0.62 =) 18.6 gpd.

Combining the affects of temperature and pressure, and using the data from the examples, the TCF is 1.5 and the PCF is 0.62.

$$\text{Estimated flow rate (gpd)} = \frac{\text{Standard flow rate x PCF}}{\text{TCF}}$$

$$\text{Estimated flow rate (gpd)} = \frac{30 \times 0.62}{1.5} = 12.4 \text{ gpd}$$

Although these calculations can be tedious, they can be important when comparing the amount of water required with the amount of water a reverse osmosis system can actually produce.

Recovery is a third measure of performance. It compares the amount of product water produced versus the amount of waste water sent to drain. Recovery can be important because it is a measure of system efficiency. The higher the recovery, the less water is sent to drain for every gallon of product water.

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One expression for recovery is recovery ratio. For example, a 1:3 recovery ratio means that for every gallon of product water, three gallons of waste water go to drain. Another expression for recovery is % recovery:

$$\% \text{ Recovery} = \frac{\text{Product flow} \times 100}{\text{Feed flow}} = \frac{\text{Product flow} \times 100}{\text{Product flow + Conc. flow}}$$

If the recovery ratio is 1:3, the % recovery is (1/(1+3) =) 0.25 (25%).

As noted earlier, the product flow can vary with temperature and Net Driving Pressure. In reverse osmosis systems using a capillary tube or other "fixed orifice" flow restrictor, the concentrate flow varies with pressure. For these systems, a similar Pressure Correction Factor used for product flow estimates can be used for concentrate flow estimates. In this case, the PCF for the concentrate flow would be the actual water pressure divided by the standard pressure.

For example, consider a 30 gpd-rated system with a standard recovery of 50% (1:1 ratio). If the water pressure is 60 psi, the TDS is 1400 mg/L, and the product pressure is 20 psi, the estimated product flow would be 12.4 gpd. The PCF for the concentrate flow would be (60/50 =) 1.2, so the estimated concentrate flow would be (30 x 1.2 =) 36 gpd. Therefore, under these conditions,

$$\% \text{ Recovery} = \frac{12.4 \text{ gpd} \times 100}{12.4 \text{ gpd} + 36 \text{ gpd}} = 25.6\% \text{ (about 1:3 ratio)}$$

Note that the calculated recovery is significantly lower than the standard recovery. Performing the calculation can help provide accurate information to customers concerned about system efficiency.

Operating a reverse osmosis system at high recovery will increase efficiency, but it also will increase the risk of membrane fouling and the TDS of the product water. This is because a higher recovery will increase the average TDS of the water inside the reverse osmosis element. This increase can be estimated with a concentration factor (CF).

$$CF = \frac{1}{(1-Y)}, \text{ where } Y = \% \text{ recovery expressed as a decimal fraction}$$

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For example, if the recovery is 25%, Y is 0.25, and the Concentration Factor is (1/0.75 =) 1.33. The table below shows Concentration Factors versus Recovery.

% Recovery	Recovery Ratio	Concentration Factor
17	1:5	1.2
20	1:4	1.25
25	1:3	1.33
33	1:2	1.5
50	1:1	2.0
67	2:1	3.0
75	3:1	4.0
80	4:1	5.0

If the TDS of the feed water is 1400 mg/L and the % Recovery is 50%, the estimated TDS of the concentrate water is 2800 mg/L. If the % Recovery were 25%, the concentrate water TDS would be about 1860 mg/L. The average TDS of the water that goes through the membrane would be the average of the feed and concentrate TDS levels. For 50% recovery, that would be 2100 mg/L, and for 25% recovery, that would be 1630 mg/L. Since product water quality is a function of % rejection, operating at a lower recovery will result in a lower TDS level in the product water.

The Concentration Factor also can be used to estimate levels of specific items in the water, except for pH. These numbers can be used to estimate the scaling potential for substances such as calcium sulfate. Because many of these calculations are cumbersome, they are best performed with a computer using the Culligan CAAP (Computer Aided Application Program) software.

Service Flow and Components. For a typical drinking water system, feed water first passes through a particulate filter cartridge to remove particles as small as 5 microns. Next, the water passes through an activated carbon filter to remove free chlorine, which could damage the reverse osmosis membrane. Some of the filtered water passes through the reverse osmosis membrane and is sent to a pressure tank, where it is stored for use. The remainder of the water, the concentrate water, is sent to drain. When the pressure in the product water tank reaches approximately 66% of the feed pressure, an automatic shutoff valve closes the feed water line to prevent a continuous flow of water to drain and to extend the life of the filters and element. An optional booster pump, used to increase the product flow and/or to improve the product water quality, shuts off via a pressure switch. When the product water faucet is opened, water passes from the pressurized storage tank through an activated carbon polishing filter, and then to the faucet.

Commercial reverse osmosis systems operate in essentially the same way as drinking water systems. Some include an activated carbon filter, and others include pressure pumps as standard equipment. Storage tanks and faucets are not included due to the wide variety of potential uses for the product water.

Product Specifications

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* 3 Gallon Storage Tank

Model	Product Flow (gpd)	% Recovery	% Rejection
CWT-35	35	43	88
AC-30*	30	43	83.2

Standard conditions for the performance specifications in the table are a feed water temperature of 77°F, pressure of 50 psig, and TDS of 500 mg/L.

Application

Booster pump. A booster pump is used to increase the Net Driving Pressure to produce more water and/or to increase the quality of the product water. It is recommended if the TDS of the feed water is higher than 1500 mg/L. A booster pump should not be used to increase the product flow above rated flow (e.g., to get more than 30 gpd from a unit rated at 30 gpd). Doing so will result in rapid membrane fouling. Alternatives to higher flow are higher-rated RO elements, multiple elements, or a larger product water storage tank.

Softener. A water softener commonly is used as pretreatment to a reverse osmosis system to prevent hardness fouling. There are other reasons for softening the water, but if the only reason is RO pretreatment, note that softening is not always required. For those applications, use the CAAP software to determine the scaling potential of the feed water. Often, reducing the system recovery, sending more concentrate water to drain, can prevent fouling by hardness scale.

Nitrate. The rejection of nitrate is dependent on net driving pressure. The minimum recommended pressure is 40 psi to ensure adequate reduction of nitrate. Adding a booster pump and reducing the recovery can help in these applications.

Cysts. Some drinking water systems are certified to reduce levels of cyst-forming microorganisms such as Giardia or Crytosporidium.

VOC's. Volatile organic chemicals such as chloroform and MTBE have been reported as contaminants in some drinking water supplies. These reports have resulted in many calls from customers, asking if their reverse osmosis drinking water system will remove these substances. The answer is no. The reverse osmosis process is intended primarily to reduce the level of dissolved ions; VOC's are not ionic or only weakly so. Reverse osmosis may reject dissolved non-ionic molecules with a molecular weight higher than 250 Daltons, but many VOC's have a lower molecular weight. Use an activated carbon system specifically certified for VOC reduction.

Arsenic. Some drinking water systems are third-party certified to reduce arsenic, but this applies only to As(V), arsenate, and not to As(III), arsenite. The certification is valid only if the water is chlorinated. Chlorine will oxidize As(III) to As(V) with a contact time of one minute. The chlorine should not be removed until just prior to the reverse osmosis system. As(V) may react with metallic plumbing and be converted back to As(III).

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Silica. Silica scale on the reverse osmosis membrane may be a problem if the % recovery is too high for the level of silica in the feed water. Refer to the section on Silica in Chapter 3, Causes, to determine silica solubility at the specific water temperature of the application. Using the concentration factor calculations from this section, determine the silica concentration in the wastewater. If the silica level in the wastewater exceeds the solubility limit, the system recovery must be reduced to prevent silica fouling.

pH change. For a given pH level, the ratio of the bicarbonate alkalinity level to the pH level is constant. As the pH decreases, this "R Value" decreases, and vice versa. During the reverse osmosis process, a small percentage of bicarbonate alkalinity passes through the membrane. As with other dissolved gasses, carbon dioxide is not rejected by the membrane. The result is a decrease in the R Value, and a decrease in the pH of the product water. The concentrate water has an increased level of bicarbonate, but the same level of carbon dioxide. Since the R Value is higher, the pH of the concentrate water is higher than the pH of the feed water. Calculations used to estimate the pH of the product and waste waters can be found in the Appendices.

Free Chlorine. Free chlorine (hypochlorite, ClO-1) can reduce the life of thin film composite (TFC) reverse osmosis membrane. Although the specification for maximum allowable free chlorine in the feed water typically is stated as 0 mg/L, a more detailed specification is 1000 mg/L-hours (recent research suggests that TFC membranes may tolerate up to 12,000 mg/L-hours; however, until membrane manufacturers endorse this data, stay with the current specifications to protect warranty coverage). Divide the free chlorine level into 1000, and the result is the number of hours of estimated membrane life before damage becomes evident through a decrease in % rejection. For example, if the free chlorine level is 0.5 mg/L, the estimated life is 2000 hours, or about 12 weeks. This is why applications where the water contains free chlorine require activated carbon to remove the chlorine prior to the membrane.

Chloramines. Chloramines are formed by a combination of free chlorine and ammonia, usually where both chemicals are fed into a public water supply. In general, chloramines will not damage a reverse osmosis membrane. However, if the pH of the water is 9.0 or higher, the presence of chloramines will cause the membrane to swell and the rejection to drop as low as 60%. The membrane will shrink back to its original size and perform normally if the pH is reduced below 9.0.

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Products

Ultraviolet Systems

Ultraviolet systems are available for reduction of biogrowth, generation or destruction of ozone, and reduction of Total Organic Carbon. This section focuses on UV for reduction of biogrowth.

Process

Ultraviolet energy is a form of light with a wavelength below that of visible light and above that of x-rays. Ultraviolet systems for microbial control operate at a specific wavelength of 254 nanometers. At this wavelength, the ultraviolet energy can break down the DNA in microorganisms and prevent their reproduction, a process called inactivation.

Capacity

In order to ensure adequate inactivation UV dosage, the energy must be strong enough, and the microorganism must be exposed to the energy for a minimum period of time. The term used to indicate both energy and time is milli-Joules per square centimeter (mJ/cm2). Guidelines for the dosage required from UV systems depend on the type of microorganisms present:

Class A systems are for inactivation of bacteria, viruses, Cryptosporidium oocysts, and Giardia cysts. The minimum required dosage for these systems is 40 mJ/cm2.

Class B systems are for inactivation of non-pathogenic, nuisance microorganisms only. The minimum required dosage for these systems is 16 mJ/cm2 at 70% of the normal output of the UV lamp.

For a fixed UV energy output, the system is sized by flow rate.

Model	Maxima (Class A)	Proxima (Class B)
U1	4 gpm	5 gpm
U2	10 gpm	13 gpm
U4	18 gpm	24 gpm
U7	30 gpm	40 gpm
U10	40 gpm	53 gpm

Components

An Ultraviolet system includes a stainless steel disinfection chamber. For residential systems, the chamber is 3-4 inches in diameter and 20-40 inches long. A quartz sleeve goes down the center of the chamber and is sealed with an o-ring. An ultraviolet lamp fits into the quartz sleeve, which prevents contact between the water and the lamp while allowing the UV radiation to pass through.

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A control box contains the power source for the UV bulb, an operating time indicator, audible and visual alarms for lamp failure, and a relay for operating a Normally Closed solenoid valve to shut off water to service in the event of failure. The control box for Class A systems also includes a monitor to ensure that the UV bulb is transmitting the proper UV dosage at the proper wavelength.

Application

Pretreatment. In order for the UV radiation to inactivate microorganisms, it must be able to reach them. The water quality standards in the following table are intended to ensure that the radiation will be able to pass through the water, and that there will be no deposits on the quartz tube.

Contaminant	Maximum
Suspended Solids	5 mg/L
Color	None
Iron	0.3 mg/L
Manganese	0.05 mg/L
pH	6.5 – 9.5
Hardness*	120 mg/L
Hydrogen Sulfide	0.05 mg/L

*The Langlier Saturation Index (LSI) of the water should be negative. See the Appendices for LSI calculations.

Heat. The UV lamp produces a small amount of heat, which is carried away by the water flow. If the unit is located in a warm environment and there is no water flow for an extended period, the water may heat up. The temperature should not exceed 100°F, or the wavelength of the UV radiation may change to the point where inactivation does not occur. In these cases a Normally Closed solenoid valve can be installed in a tee on the service line and activated by a cycle timer to flush water to drain periodically.

Cysts. Although Class A UV systems are third-party certified to inactivate Cryptosporidium oocysts and Giardia cysts, they are not certified to inactivate other cysts that may also be in the water supply. General removal of cysts will require a system certified for cyst reduction ahead of the UV system.

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Products

CUL-CLEER SYSTEMS

A Cul-Cleer system is a concept rather than a product. It consists of one or more chemical feeders, contact or retention tank(s), and filter(s). The chemicals are used for oxidation, coagulation, pH adjustment, and corrosion prevention.

Perhaps the most important component of a Cul-Cleer system is an informed, involved customer. These systems can be complex and require regular monitoring and maintenance. If the customer is not willing to be involved with the system, eventually it will not work, no matter how well designed.

Chemicals

Alum (potassium aluminum sulfate, $KAl(SO_4)_2$). Alum is used as a coagulant to remove small suspended solids. It forms a jelly-like floc that slowly settles in water and sweeps particles from the water as it settles. The typical alum dosage level is 20-30 mg/L. The pH of the water is critical for proper alum floc formation, since the floc will not form at low or high pH levels. The ideal pH range for alum floc formation is 7.2 to 7.5. An alum solution is acidic, so it may have an affect on the pH of the water.

The alum floc is relatively fragile, so it must settle in a retention tank. If the floc goes to a depth or cartridge filter, the high flow velocity between the media particles or fibers will break the floc apart. Even high turbulence in a pipe can break the floc apart, so this is one chemical where the use of a static mixer is not recommended.

Chlorine (bleach, NaClO or Cl_2). Bleach is a solution of chlorine, made by bubbling chlorine gas through a dilute solution of caustic. It is used to oxidize clear water iron and hydrogen sulfide, and to kill bacteria. It can be used to oxidize soluble manganese, but the reaction usually is too slow if the pH of the water is below 9. The following table shows the dosage of chlorine (mg/L) required for each mg/L of contaminant.

Mg/L	Iron (Fe^{+2})	Manganese (Mn^{+2})	Hydrogen Sulfide (H_2S)
Chlorine (Cl_2)	0.64	1.3	8.3

The dosage level of bleach required for killing bacteria and other microorganisms depends on the type of microorganism, the temperature and pH of the water, and the amount of time the chlorine is in the water. The graphs below indicate these influences.

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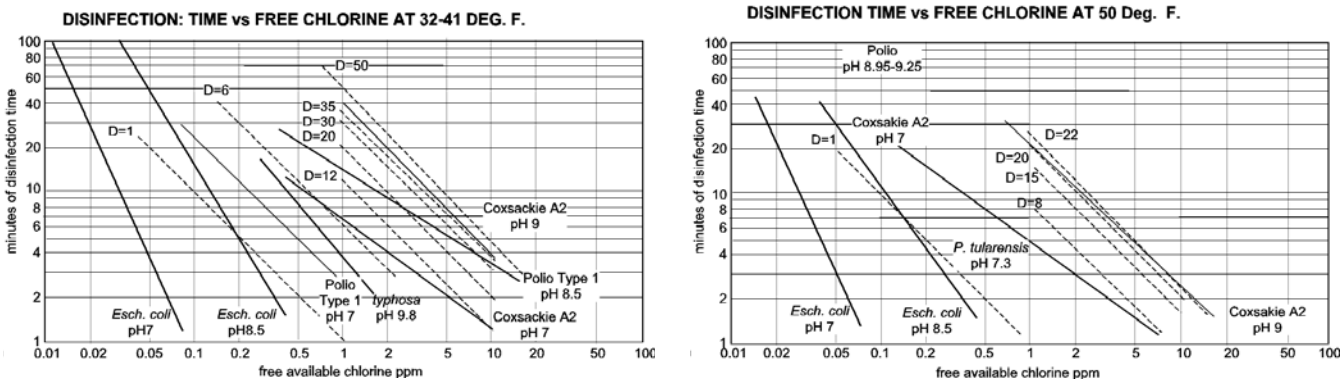

E.R. Baunson and D.D. Luderz, "Free Available Chlorine Residuals for Swell Non-Public Water Supplies", Reprinted for Jawwa, Vol. 53, No. 11, Nov. 1962.

1. Pick the graph that represents the coldest probable temperature of the water to be treated.
2. Have the customer choose the microorganisms for which protection is desired.
3. Pick the D factor (dashed) line that is wholly to the right of the organism line at the pH of the water to be treated. This D factor line will give a 99% kill for that specific organism at that specific, or lower, pH. Choose the combination of contact time and free chlorine residual that will result in at least the necessary D factor.

The most common pathogenic microorganism to be treated is E. coli bacteria. The typical contact time is twenty minutes (120 gallon contact tank with a flow of 6 gpm), and the typical free chlorine residual requirement is 0.5-1 mg/L. As can be seen from the graphs, the resulting minimum D factor of 10 should be more than adequate to achieve 99% kill regardless of temperature and at pH levels up to 8.5.

Citric acid ($H_8C_6O_7$). Citric acid is considered a weak acid, although it is about as strong as phosphoric acid. Its primary use is for cleaning rust from ion exchange resin. Occasionally it is used to reduce the pH of a water supply. Because of its high molecular weight (192), the dosage required would be 5.3 times higher than the dosage required for hydrochloric acid (see below).

F-86 Polymer Coagulant. F-86 is a synthetic chemical composed of large "sticky" organic molecules. Small particles stick to the large molecule to form a large particle that can be filtered from water with a depth filter or cartridge filter. The advantage to using a polymer chemical is that no retention tank is required. The disadvantage is that the polymer dosage must be matched to the level of suspended solids. If the polymer is under-dosed, there will not be enough for all the particles to stick. If the polymer is over-dosed, it will actually disperse the particles. For residential applications where the level of suspended solids changes, an alternative coagulant is recommended.

The typical F-86 polymer coagulant dosage is 1-2 mg/L. Jar testing should be done to determine the optimum dosage level (see Chapter 3, Testing).

Fer-Sul chemical (potassium permanganate, $KMnO_4$). Potassium permanganate is used in a chemical feed system installed ahead of a continuous-feed Cullsorb® system. It is the only chemical recommended for oxidizing soluble manganese, since it does not require a high pH for rapid oxidation. It also will oxidize clear water iron and hydrogen sulfide. The following table shows the dosage of potassium permanganate (mg/L) required for each mg/L of contaminant.

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Mg/L	Iron (Fe^{+2})	Manganese (Mn^{+2})	Hydrogen Sulfide (H_2S)
Potassium Permanganate ($KMnO_4$)	0.94	1.9	12.4

If the water contains iron and/or hydrogen sulfide, chlorine can be fed to oxidize these contaminants first, followed by potassium permanganate feed to oxidize the manganese. This arrangement will lower chemical costs. Whichever is chosen, the water entering the filter should be monitored regularly to verify it has a light pink color. Overfeeding will result in pink water to service, while underfeeding will result in stripping of the Cullsorb media and soluble manganese going to service.

Hydrochloric acid (Muriatic acid, HCl). Hydrochloric acid is used to reduce the pH of a water supply. It can be found in hardware stores and pool stores for etching concrete and adjusting the pH of pool water. The dosage required is dependent on the initial pH level, the alkalinity level, and the desired pH level. The best way to calculate the required dosage is with the CAAP software program, but the following calculation can be used.

1. Refer to the table to determine the "R Factor" for the existing pH level.

pH versus R Factor

pH	R	pH	R	pH	R	pH	R
4.3	0.010	5.3	0.10	6.3	1.0	7.3	10
4.4	0.012	5.4	0.13	6.4	1.3	7.4	13
4.5	0.016	5.5	0.16	6.5	1.6	7.5	16
4.6	0.020	5.6	0.20	6.6	2.0	7.6	20
4.7	0.025	5.7	0.25	6.7	2.5	7.7	25
4.8	0.032	5.8	0.32	6.8	3.2	7.8	32
4.9	0.040	5.9	0.40	6.9	4.0	7.9	40
5.0	0.050	6.0	0.50	7.0	5.0	8.0	50
5.1	0.063	6.1	0.63	7.1	6.3	8.1	63
5.2	0.079	6.2	0.79	7.2	7.9	8.2	79

2. Divide the existing alkalinity level by the R Factor. This is the estimated carbon dioxide (CO_2) level.
3. Determine the desired pH of the treated water, then refer to the table to determine the "R Factor" for the desired pH level.
4. Multiply the R Factor from Step 3 times the CO_2 level from Step 2. Subtract this value from the alkalinity.
5. Multiply the R Factor from Step 3 times 1.205. Add 1.37 to this value.
6. Divide the result of Step 4 by the result of Step 5. This is the dosage of hydrochloric acid required to lower the pH from the existing level to the desired level.

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Example: The pH is 8.2, the alkalinity is 150 mg/L, and the desired pH is 7.3.

1. At a pH of 8.2, the R Factor is 79.
2. The carbon dioxide level is (150/79 =) 1.9 mg/L
3. At a pH of 7.3, the R Factor is 10.
4. 10 x 1.9 = 19, and 150 – 19 = 131.
5. 10 x 1.205 = 12.05, and 12.05 + 1.37 = 13.42
6. 131/13.42 = 9.8 mg/L HCl dosage required to reduce the pH from 8.2 to 7.3.

Hydrogen Peroxide (H_2O_2). Hydrogen peroxide is the most powerful of the common oxidizing agents fed with a chemical feeder. Its primary use is for oxidation of hydrogen sulfide. Although it also can oxidize iron, field reports indicate that the reaction commonly produces colloidal iron that is difficult to remove with a filter. As with chlorine, the reaction between hydrogen peroxide and soluble manganese is relatively slow.

The following table shows the dosage of hydrogen peroxide (mg/L) required for each mg/L of contaminant.

Mg/L	Iron (Fe^{+2})	Manganese (Mn^{+2})	Hydrogen Sulfide (H_2S)
Hydrogen Peroxide (H_2O_2)	0.30	0.62	4.0

Hydrogen peroxide also has been used successfully to kill microorganisms. However, the minimum concentration (0.25% by weight) and contact time (6 hours) make hydrogen peroxide disinfection impractical for chemical feed systems.

Hydrogen peroxide solutions must be prepared with deionized water to prevent degradation of the peroxide. The solutions tend to produce gas bubbles, so a peristaltic pump (e.g., Stenner) must be used to prevent loss of pump prime. Finally, the strong oxidizing power of hydrogen peroxide can cause relatively rapid breakdown of coal-based activated carbon. Coconut-shell based activated carbon (Cullar® CC media) should be used to remove excess hydrogen peroxide.

Polyphosphates (sodium hexametaphosphate, $(NaPO_3)_6$, P-33, P-34, and P-324). Polyphosphates tie up (chelate) ions like copper, clear water iron, calcium, and magnesium to prevent scale and stains. Because water softening is a more efficient process for removing these ions, the primary use of polyphosphates is to prevent staining due to corrosion. In the presence of a small amount of hardness (0.5 – 1 gpg), the polyphosphate also can put a coating on the piping to prevent corrosion. Field reports indicate that a hardness level over 2 gpg may cause the polyphosphate to remain in the water rather than coating the piping. If the chemical is being fed after a softener, a small amount of hardness can be bled to service by installing a needle valve between the hard and soft lines and adjusting the valve to achieve the desired hardness level.

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Products

P-33 chemical is a polyphosphate powder for mixing with water. P-34 chemical consists of large crystals of polyphosphate that dissolve slowly as water passes through a Rust-Gard pot feeder. P-324 chemical contains sodium silicate to improve coating of the pipe. Silicate also requires hardness to form the coating.

The maximum dosage for P-33 and P-324 chemicals is 10 mg/L, which also is the maximum level for potable water. After feeding the chemical at this level for a few months to put a coating on the piping, the dosage typically is cut back to a maintenance level of 5 mg/L.

Soda Ash (Sodium Carbonate, Na_2CO_3). Soda ash is used to increase the pH of a water supply. The dosage required is dependent on the initial pH level, the alkalinity level, and the desired pH level. The best way to calculate the required dosage is with the CAAP software program, but the following calculation can be used.

1. Refer to the table to determine the "R Factor" for the existing pH level.

   pH versus R Factor

pH	R	pH	R	pH	R	pH	R
4.3	0.010	5.3	0.10	6.3	1.0	7.3	10
4.4	0.012	5.4	0.13	6.4	1.3	7.4	13
4.5	0.016	5.5	0.16	6.5	1.6	7.5	16
4.6	0.020	5.6	0.20	6.6	2.0	7.6	20
4.7	0.025	5.7	0.25	6.7	2.5	7.7	25
4.8	0.032	5.8	0.32	6.8	3.2	7.8	32
4.9	0.040	5.9	0.40	6.9	4.0	7.9	40
5.0	0.050	6.0	0.50	7.0	5.0	8.0	50
5.1	0.063	6.1	0.63	7.1	6.3	8.1	63
5.2	0.079	6.2	0.79	7.2	7.9	8.2	79

2. Divide the existing alkalinity level by the R Factor. This is the estimated carbon dioxide (CO_2) level.
3. Determine the desired pH of the treated water, then refer to the table to determine the "R Factor" for the desired pH level.
4. Multiply the R Factor from Step 3 times the CO_2 level from Step 2. Subtract the alkalinity from this value.
5. Multiply the R Factor from Step 3 times 0.415. Add 0.94 to this value.
6. Divide the result of Step 4 by the result of Step 5. This is the dosage of soda ash required to raise the pH from the existing level to the desired level.

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Example: The pH is 6.2, the alkalinity is 50 mg/L, and the desired pH is 7.3.

1. At a pH of 6.2, the R Factor is 0.79.
2. The carbon dioxide level is (50/0.79 =) 63.3 mg/L
3. At a pH of 7.3, the R Factor is 10.
4. 10 x 63.3 = 633, and 633 – 50 = 583
5. 10 x 0.415 = 4.15, and 4.15 + 0.94 = 5.09
6. 583/5.09 = 115 mg/L Na_2CO_3 dosage required to raise the pH from 6.2 to 7.3.

The above calculation applies only to "anhydrous" soda ash, Na_2CO_3. Some soda ash products are hydrated (contain water molecules), e.g., $Na_2CO_3.10H_2O$ (washing soda). If washing soda is used, the required dosage will be 2.7 times higher than for anhydrous soda ash.

Some dealers are using potassium carbonate, K_2CO_3, instead of soda ash to limit the sodium increase after chemical feed. To achieve the same pH increase, potassium carbonate should be fed at 1.3 times the rate of soda ash.

Sodium hydroxide (caustic, NaOH) is more effective at raising the pH than soda ash. However, an upset in the chemical feed system may lead to caustic burns. For this reason, caustic feed generally is not recommended. Contact an application engineer if you think caustic feed is needed for a particular application.

Chemical compatibility. After being injected into the water flow, the chemicals listed above are generally compatible. Chlorine may oxidize some polymers, which can be compensated by increasing the polymer dosage.

A few of the concentrated chemicals may be mixed in the same solution tank. Although this will reduce the number of chemical feed systems required, it will make the system less flexible in controlling the dosages of each chemical. The primary concern when mixing concentrated chemicals is that there may be a reaction that produces toxic fumes or intense heat. DO NOT mix concentrated chemicals in the same solution tank unless you are certain no undesirable reaction will occur.

1. Soda ash, caustic, and chlorine bleach are compatible.
2. Acids are compatible with alum.
3. P-33 and P-324 chemicals are compatible with soda ash.
4. Consider all other chemical combinations as NOT compatible.

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Chemical Feeders

A wide variety of chemical feeders are available in the Culligan system. Outputs vary from as low as 0.2 gpd (gallons per day) up to 240 gpd. Although the brand of feeder chosen may be a personal preference, the output of the feeder should be determined to ensure proper application.

Water flow rate. The first step in feeder sizing is to determine the flow rate of the water into which the chemical will be injected.

If the chemical will be injected ahead of a pressure tank in a well system, the flow rate will be the well pump flow rate. Refer to the Appendices for information on measuring the well pump flow rate.

For municipal systems, or where the chemical will be injected after the pressure tank, the flow rate is the service flow rate, which must be determined by a fixture count. In most homes, the result will be in the range of 5-10 gpm. However, homes with whirlpool tubs or multi-head showers often will use water at least double the normal rate.

Dosage. Determine the chemical dosage based on the contaminant level and the dosage information provided in the Chemicals section.

Solution concentration. The final item of information needed for feeder sizing is the concentration of the chemical solution that will be fed.

For solid chemicals, the concentration is limited by the maximum solubility, as shown in the following table.

Solid Chemical	Solubility, Max. (lb/gal)
Alum ($KAl(SO_4)_2$)	1.5
P-33, P-324	1.0
Fer-Sul ($KMnO_4$)	0.2
Soda Ash (Na_2CO_3)	1.0
Washing Soda ($NaHCO_3$)	3.5

In general, it is best to size a feeder using a solution strength of no more than half the solubility of the solid.

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For liquid chemicals, the concentration of the undiluted chemical can be used, as shown in the following table.

Liquid Chemical	Solution Strength (lb/gal)
Bleach, 5.25%	0.44
Bleach, 10%	1.0
Bleach, 15%	1.25
Citric acid	12.9
F-86	9.6
Hydrochloric acid, 31.5%	3.04
Hydrogen peroxide, 3%	0.25
Hydrogen peroxide, 7.5%	0.63

If the chemical to be used does not appear in the tables, consult the chemical supplier for information.

Feeder sizing calculation. Once the chemical dosage, water flow rate, and solution concentration are known, the chemical feed rate can be calculated.

$$\text{Feed Rate (gpd)} = \frac{\text{Dosage (mg/L)} \times \text{Flow Rate (gpm)}}{83.2 \times \text{Solution Conc. (lb/gal)}}$$

Example: Household bleach (5.25%, 0.44 lb/gal) will be fed at a dosage of 5 mg/L into a flow rate of 7 gpm.

$$\text{Feed Rate (gpd)} = \frac{5 \text{ mg/L} \times 7 \text{ gpm}}{83.2 \times 0.44 \text{ lb/gal}} = 0.96 \text{ gpd}$$

The calculated feed rate represents the minimum feeder size. In general, the chosen feeder should have a maximum output at least double the calculated feed rate. Note that, in the example, a feeder could be chosen that would allow bleach to be fed directly from the bleach container. In many applications, proper sizing of the chemical feeder eliminates the need for a solution tank and minimizes chemical handling.

If a solution tank is used, it will be helpful for the installer to know how much chemical to mix with water to make the solution. The calculation for solid chemicals is different than that for liquid chemicals

(Solid)

$$\text{Solution Conc. (lb/gal)} = \frac{\text{Dosage (mg/L)} \times \text{Flow (gpm)}}{83.2 \times \text{Feed Rate (gpd)}}$$

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Example: Soda ash will be fed at a dosage of 50 mg/L into a flow rate of 10 gpm using a 24 gpd feeder. To allow for adjustability, the feeder will be set to 50% output, or 12 gpd.

$$\text{Solution Conc. (lb/gal)} = \frac{50 \text{ mg/L} \times 10 \text{ gpm}}{83.2 \times 12 \text{ gpd}} = 0.50 \text{ lb/gal}$$

After performing the calculation, the result should be compared to the maximum solubility of the solid chemical. If the calculated value exceeds the maximum solubility, a larger chemical feeder will be needed.

(Liquid)

$$\text{Solution Conc. (mL/gal)} = \frac{45.5 \times \text{Dosage (mg/L)} \times \text{Flow (gpm)}}{\text{Solution Conc. (lb/gal)} \times \text{Feed Rate (gpd)}}$$

Example: Hydrogen peroxide (3%, 0.25 lb/gal) will be fed at a dosage of 25 mg/L into a flow rate of 6 gpm using a 17gpd feeder. The feeder will be set at 50% output, or 8.5 gpd

$$\text{Solution Conc. (mL/gal)} = \frac{45.5 \times 25 \text{ mg/L} \times 6 \text{ gpm}}{0.25 \text{ lb/gal} \times 8.5 \text{ gpd}} = 3212 \text{ mL/gal}$$

After comparing the calculation, be sure that the result does not exceed 3785, the number of mL in a gallon. If it does, a larger feeder may be required.

Chemical usage. Unless the water is flowing constantly, the chemical usage will be less than the chemical feed rate. To determine the gallons of chemical used per day,

1. Multiply the water flow rate times 1440 (minutes per day).
2. Determine the average daily water usage.
3. Divide the value from Step 2 by the value from Step 1.
4. Multiply the chemical feed rate by the value from Step 3.

Example: The water flow rate is 7 gpm, the average daily water usage is 400 gpd, and the chemical feed rate is 15 gpd.

1. 7 gpm x 1440 min/day = 10,080 gpd
2. A family of 4 at 100 gpd per person, or 400 gpd
3. 400 gpd/10080 gpd = 0.04
4. 0.04 x 15 gpd = 0.6 gallons of chemical used per day

This value can be used to determine how often the chemical solution must be prepared. Multiplying the gallons used by the solution concentration will indicate how many pounds of chemical will be used per day, which can be used to estimate chemical costs.

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Chemical Feeder Activation. Chemical feed should be started and stopped using a method that will ensure a reasonably constant dosage level. If the chemical injection point is ahead of a well pressure tank, the well pump pressure switch can be used to activate the feeder. If the injection point is after the pressure tank, or if there is no pressure tank (e.g., a public water supply), a flow meter pulser or similar system should be used to control the chemical feeder. These systems control the feeder based on the service flow rate. A flow switch should not be used to activate the feeder unless the service flow rate is constant when the water is flowing.

Contact and Retention Tanks

Some chemical reactions occur almost instantly, while other reactions may require some contact time. Other reactions may produce suspended solids that need to settle out in a tank prior to filtering the water.

Reaction Speed	Chemical Reaction
Immediate	pH change with acid, soda ash Polyphosphate chelation F-86 coagulation
2-5 minutes	Oxidation of iron, hydrogen sulfide
Settling (20 minutes)	High iron, alum feed application
Microorganism control	(see section on Chlorine, above)

Static mixers. In order for chemicals to react with substances in water, they must be mixed into the water. A static mixer accomplishes the mixing by having the water pass through a series of baffles. The high level of turbulence created by the baffles mixes the chemical with the water very quickly. As noted earlier, a static mixer should not be used with alum because the turbulence will break apart the alum floc. The alternative to a static mixer is a series of 90° ells, which also create turbulence for mixing.

Contact tanks. The purpose of a contact tank is to hold the treated water for a period of time to allow chemical reactions to be completed. The tank should be sized based on the maximum service flow rate and the required contact time.

Tank size (gal) = Flow Rate (gpm) x Contact Time (min)

Example: Clear water iron at a concentration less than 20 mg/L is being oxidized by chlorine. The service flow rate is 7 gpm, and the desired contact time is 5 minutes.

Tank size (gal) = 7 gpm x 5 minutes = 35 gallons.

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Retention tanks. In addition to contact time, a retention tank is intended to retain the suspended solids produced by chemical reactions. In general, a retention tank should be used if the expected suspended solids level is greater than 20 mg/L. In order to prevent the water from carrying the suspended solids to service, the flow in the tank must be slowed down considerably. This requires a relatively large diameter tank that usually must be specially constructed for the purpose. Refer to the appendix for design details on retention tanks.

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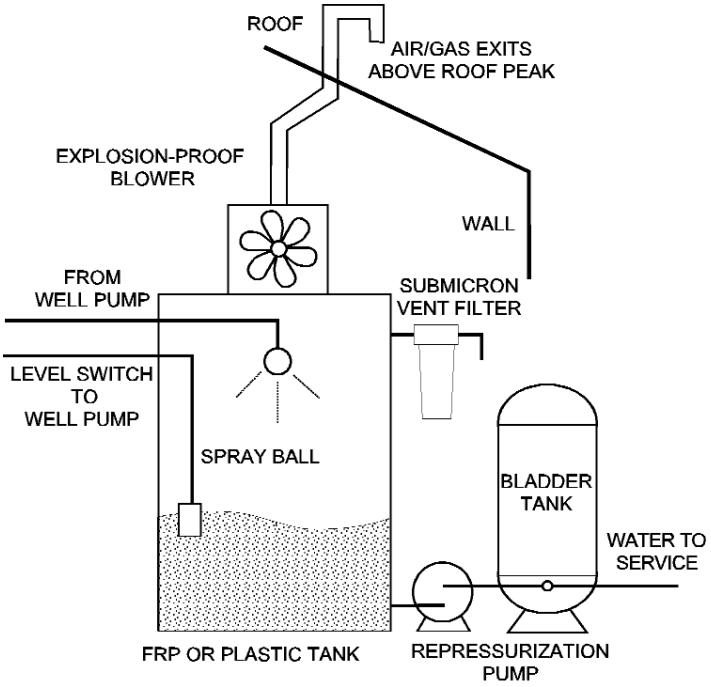
AERATION SYSTEMS

Aeration systems are intended to introduce oxygen into the water, or to vent dissolved gasses from the water. Some are used for high hydrogen sulfide applications, but the primary use of a forced draft aeration system is to reduce the level of methane.



The illustration shows the components of a forced draft aeration system:

1. Water enters the top of a 100-200 gallon fiberglass or plastic tank and sprays out through a spray ball or slotted manifold assembly. A level switch controls the well pump.
2. A blower draws air into the tank through a sub-micron hydrophobic air vent filter. Because methane and hydrogen sulfide can be explosive at high concentrations, an explosion-proof motor is recommended.
3. Dissolved gasses are released from the water spray and vented out of the tank. The vent piping or ductwork must direct the gasses outside the building and above the roofline to prevent a buildup of gasses near the building.
4. The water then is repressurized with a standard well pump system.
5. Carbon filters installed in series after the repressurization system are recommended for removal of any residual methane or hydrogen sulfide.

If the water supply contains both methane and bacteria, the methane should be removed prior to chlorination. Chlorine can react easily with methane to form chlorinated methanes that are carcinogens.

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Appendices

Chemicals Used in Water Treatment

This section contains a list of chemicals and media used in water treatment. They range from common household chemicals like bleach or baking soda, to specialty chemicals like polyphosphate or F-86 polymeric coagulant. All chemicals are potentially dangerous and could cause serious injury or even death if improperly handled. Even pure water can cause death if too much is consumed.

General Chemical Safety Precautions

- Do not place or store any water treatment chemical, either full strength or diluted, in an area accessible to children
- Follow all of the chemical manufacturer's handling and safety instructions
- When using chemicals, always follow the manufacture recommendation for the use of appropriate personal protective equipment as noted in the Material Safety Data Sheet (MSDS) for that chemical
- Store concentrated chemicals only in their original containers, complete with labels, warnings and directions for use
- Do not store any chemical in an unmarked container or a container not specifically suited to the chemical
- When diluting chemicals, always add the concentrated chemical to water; never add water to concentrated chemical as it may cause violent reaction, spatter or fire
- Never mix oxidizing agents, such as bleach, peroxide, potassium permanganate [AKA Fer-Sul chemical], with reducing agents, such as sodium hydrosulfite [AKA Sofner-Gard chemical, Iron-Eater chemical, etc.] (violent reaction, spatter, burns)
- Never mix acids and alkalis together (violent reaction, spatter, burns)
- Sodium hydrosulfite [AKA Sofner-Gard, Iron Eater] is flammable when the dry chemical is exposed to small amounts of water; keep the container tightly closed in a cool, dry place
- Even simple water softener salt can pose a danger to children; it is an eye irritant and if ingested can cause vomiting and dehydration if eaten

An important source for safety information on chemicals and media is the Material Safety Data Sheet (MSDS). In the following list, items with and asterisk (*) have MSDS on file and available through Culligan (www.myculligan.com, Technical section, Technical References). For all others, obtain the MSDS from the chemical's manufacturer.

Solid Chemicals

Alum (aluminum sulfate or potassium aluminum sulfate)

Citric acid

Ironeater chemical

Potassium carbonate

Potassium chloride

Potassium permanganate (Culligan Fer-Sul chemical)*

Sodium bicarbonate (baking soda)

Sodium carbonate (soda ash)

Sodium chloride*

Sodium hydrosulfite

Sodium hexametaphosphate (polyphosphate, P-33*, P-34*)

Sodium silicate (P-324)*

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Appendices

Liquid Chemicals

Chlorine (bleach)
F-86 polyelectrolyte coagulant*
F-88 polyelectrolyte coagulant*
Hydrochloric acid (muriatic acid)
Hydrogen peroxide

Media

Birm media (Iron Cleer filter)*
Cullar CC, D, D Plus, F, G, and M Granular Activated Carbon* (D, D-Plus, F, G, and M)
Cullcite*
Culligan Iron Media (C.I.M., Super S filter)*
Cullneu media*
Cullneu C media*
Cullsan (unberbedding)*
Cullsan A
Cullsan G-50
Cullsan U
Cullsorb*
Diatomaceous earth
Macroporous anion resin (chloride form)*(CS-5)
Nitrate-specific anion resin
Strong acid cation resin (chloride form, Cullex)*(CH-1)
Strong acid cation resin (hydrogen form)*(CH-1H)
Strong base anion resin (chloride form)*(CS-1P, CS-2, CS-2HP,
Strong base anion resin (hydroxide form)*(CS-2OH,
Weak acid cation resin
Weak base anion resin*(CW-4)

*MSDS available from myculligan.com

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Sodium Content

The following table shows the sodium content of common foods. The data was taken from nutrition labels on the containers. For comparison, the recommended daily value for sodium intake is 2400 mg for an intake of 2000 calories. The blank spaces at the bottom of the table are for adding your own data from other nutrition labels.

Description	Serving Size	Sodium (mg)
Ketchup	1 Tbsp	190
Mayonnaise	1 Tbsp	80
Pudding, Instant, Vanilla	1/2 cup	385
Tuna (in water)	2 oz.	250
Peaches, canned, in syrup	1/2 cup	10
Soup, cream of mushroom	1/2 cup	870
Spaghetti sauce	1/2 cup	390
Sandwich cookies	3	210
Milk, 2%	1 cup	125
American cheese	1 slice	280
Bologna (thin sliced)	3 slices	610
Yogurt, w/fruit	8 oz	190
White bread	2 slices	250
Soda	12 oz.	35
Iceberg lettuce salad blend	3 oz	15
Ice cream, chocolate	1/2 cup	25
Chicken pot pie, frozen	9.5 oz.	1100
Orange juice, from concentrate	1/4 cup	0
Potatoes O'Brien	1/4 cup	25

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Appendices

Langlier Saturation Index

The Langlier Saturation Index (LSI) is used to estimate if calcium carbonate will precipitate from or dissolve into water. If the index is positive, calcium carbonate will precipitate; if negative, calcium carbonate will dissolve.

Calculating the LSI for a particular water requires data on calcium hardness, bicarbonate alkalinity, temperature, TDS, and pH.

1. Determine the value for calcium hardness in mg/L as $CaCO_3$.

   NOTE: *This value is not the same as total hardness, since total hardness also represents the magnesium content. Example: 200 mg/L.*
2. Refer to the table to determine the pCa factor. Example: pCa = 2.7
3. Determine the value for bicarbonate alkalinity in mg/L as $CaCO_3$. Example: 100 mg/L
4. Refer to the table to determine the pAlk factor. Example: pAlk = 2.7
5. Determine the value for TDS in mg/L and for temperature in degrees Fahrenheit. Example: 300 mg/L TDS and 55°F.
6. Refer to the table to determine the C factor for the TDS and temperature. Example: 2.45.
7. Add the values for pCa, pAlk, and C factors. This represents the pH at which calcium carbonate is just saturated (pHs). Example: 2.7 + 2.7 + 2.45 = 7.85
8. Determine the value for the pH of the water. Example: 7.5.
9. Subtract the saturation pH (pHs) from the pH of the water. This is the LSI of the water. Example: 7.5 - 7.85 = - 0.35. Since the LSI is negative, calcium carbonate scale will dissolve into this water.

   NOTE: *If the water temperature of this water was raised to 110°F, the new C factor would be 1.8, the pHs would be 7.2, and the LSI would be + 0.3. Raising the temperature of the water can change the water from non-scaling to scaling, which is why hardness scale is more of a problem in the hot water distribution system.*

Calculating the LSI for reverse osmosis systems is more complicated because the calculations must apply to the concentrate water.

1. Determine the values for calcium, bicarbonate alkalinity, and TDS in the feed water.
2. Refer to the section on Reverse Osmosis products in Chapter 5 to determine the concentration factor.
3. Multiply the calcium, bicarbonate alkalinity, and TDS levels by the concentration factor to estimate their levels in the concentrate water.
4. Refer to the section on pH calculation in this Chapter to determine the pH of the concentrate water.
5. Refer to the section above to calculate the LSI of the concentrate water.

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pCa and pAlk Factors

Calcium, mg/L	pCa	Alkalinity, mg/L	pAlk
1750	1.8	1750	1.5
1500	1.8	1500	1.5
1250	1.9	1250	1.6
1000	2.0	1000	1.7
900	2.0	900	1.7
800	2.1	800	1.8
700	2.2	700	1.9
600	2.2	600	1.9
500	2.3	500	2.0
400	2.4	400	2.1
300	2.5	300	2.2
200	2.7	200	2.4
100	3.0	100	2.7
75	3.1	75	2.8
50	3.3	50	3.0
25	3.6	25	3.3
20	3.7	20	3.4
15	3.8	15	3.5
10	4.0	10	3.7

C Factors

TDS, mg/L	40° F	50° F	60° F	70° F	80° F	90° F	100° F	110° F
1750	2.7	2.6	2.5	2.3	2.2	2.1	2.0	1.9
1500	2.7	2.6	2.5	2.3	2.2	2.1	2.0	1.9
1250	2.7	2.6	2.4	2.3	2.2	2.1	2.0	1.9
1000	2.7	2.6	2.4	2.3	2.2	2.1	2.0	1.9
900	2.7	2.6	2.4	2.3	2.2	2.1	2.0	1.9
800	2.7	2.5	2.4	2.3	2.2	2.1	2.0	1.9
700	2.7	2.5	2.4	2.3	2.2	2.0	2.0	1.9
600	2.7	2.5	2.4	2.3	2.2	2.0	2.0	1.8
500	2.7	2.5	2.4	2.3	2.2	2.0	1.9	1.8
400	2.7	2.5	2.4	2.3	2.1	2.0	1.9	1.8
300	2.6	2.5	2.4	2.2	2.1	2.0	1.9	1.8
200	2.6	2.5	2.4	2.2	2.1	2.0	1.9	1.8
100	2.6	2.5	2.3	2.2	2.1	1.9	1.9	1.8
75	2.6	2.4	2.3	2.2	2.1	1.9	1.8	1.8
50	2.6	2.4	2.3	2.2	2.1	1.9	1.8	1.7
25	2.5	2.4	2.3	2.2	2.0	1.9	1.8	1.7
20	2.5	2.4	2.3	2.1	2.0	1.9	1.8	1.7
15	2.5	2.4	2.3	2.1	2.0	1.9	1.8	1.7
10	2.5	2.4	2.3	2.1	2.0	1.9	1.8	1.7

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Appendices

pH Calculations – Reverse Osmosis and Dealkalizer Systems

When using a reverse osmosis system or chloride anion resin (CAR) system, it is normal for the pH of the treated water to be lower than that of the untreated water. The lower pH has caused some concern, but it is not necessarily a problem

The processes of reverse osmosis and chloride anion exchange reduce the level of bicarbonate alkalinity in the water, but not the carbon dioxide. The ratio of bicarbonate to carbon dioxide, the "R Value", is fixed at a given pH level.

$$R = \frac{\text{Bicarbonate Alkalinity}}{\text{Carbon Dioxide}}$$

The lower the ratio, the lower is the pH. Reducing the bicarbonate level but not the carbon dioxide results in a lower ratio, and therefore a lower pH. The following table shows this relationship.

pH versus R Factor

pH	R	pH	R	pH	R	pH	R
4.3	0.010	5.3	0.10	6.3	1.0	7.3	10
4.4	0.012	5.4	0.13	6.4	1.3	7.4	13
4.5	0.016	5.5	0.16	6.5	1.6	7.5	16
4.6	0.020	5.6	0.20	6.6	2.0	7.6	20
4.7	0.025	5.7	0.25	6.7	2.5	7.7	25
4.8	0.032	5.8	0.32	6.8	3.2	7.8	32
4.9	0.040	5.9	0.40	6.9	4.0	7.9	40
5.0	0.050	6.0	0.50	7.0	5.0	8.0	50
5.1	0.063	6.1	0.63	7.1	6.3	8.1	63
5.2	0.079	6.2	0.79	7.2	7.9	8.2	79

It is possible to estimate the pH of the treated water by calculating the carbon dioxide in the untreated water and estimating the bicarbonate level in the treated water.

$$CO_2 = \frac{\text{Bicarbonate Alkalinity}}{\text{R Value}}$$

For example, a water supply has a pH of 7.5 and a bicarbonate alkalinity of 100 mg/L. The R value is 16, so

$$CO_2 = 100/16 = 6.25 \text{ mg/L}$$

At 90% removal of bicarbonate alkalinity, the treated water will have a bicarbonate level of 10 mg/L. The R value of this water will be (10/6.25) = 1.6, which corresponds to a pH of 6.5.

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With reverse osmosis systems, the pH of the concentrate water will be higher.

1. Refer to the reverse osmosis section in Chapter 5 to calculate the concentration factor.
2. Multiply the bicarbonate alkalinity level of the feed water by the concentration factor to estimate the level in the concentrate water.
3. Calculate the carbon dioxide level in the feed water, which will be the same level in the concentrate water.
4. Divide the estimated bicarbonate alkalinity in the concentrate water by the carbon dioxide level. This is the R value for the pH in the concentrate water.
5. Refer to the table to estimate the pH in the concentrate water.

Example: The pH is 7.3, the bicarbonate alkalinity is 100 mg/L, and the reverse osmosis system is operating at 50% recovery.

1. The concentration factor is 2.
2. 100 x 2 = 200 mg/L bicarbonate alkalinity in the concentrate water
3. CO_2 = 100/16 = 6.25 mg/L carbon dioxide in the feed and concentrate water.
4. 200/6.25 = 32, the R Value for the pH in the concentrate water.
5. The pH corresponding to a R Value of 32 is 7.8.

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US EPA Drinking Water Standards

The 1974 Safe Drinking Water Act gives the Environmental Protection Agency (EPA) the authority to set drinking water standards. Drinking water standards are regulations that EPA sets to control the level of contaminants in the nation's drinking water. In most cases, EPA delegates responsibility for implementing drinking water standards to states and tribes.

National Primary Drinking Water Regulations are legally enforceable standards that apply to public water systems. Primary standards protect public health by limiting the levels of contaminants in drinking water. The tables below divide these contaminants into:

- Inorganic chemicals
- Radionuclides
- Disinfectants
- Disinfection byproducts
- Microorganisms

A National Secondary Drinking Water Regulation is a non-enforceable guideline regarding contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards.

Drinking water standards apply to public water systems, which provide water for human consumption through at least 15 service connections, or regularly serve at least 25 individuals. Public water systems include municipal water companies, homeowner associations, schools, businesses, campgrounds and shopping malls.

The above information, and the information in the tables below, came from the EPA website (www.epa.gov/safewater/mcl.html) in February, 2003. Because the drinking water standards are reviewed and updated on a regular basis, the site should be visited frequently to determine if there have been any changes. State or local drinking water standards also should be reviewed, since they may take precedence over the national standards. It is your responsibility to be familiar with and comply with all local, state and federal laws and regulations.

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Inorganic Chemical	MCL (mg/L)	Potential Health Problem
Antimony	0.006	Increase in blood cholesterol; decrease in blood sugar
Arsenic	0.010 as of 01/23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer
Asbestos (fiber >10 micrometers)	7 MFL	Increased risk of developing benign intestinal polyps
Barium	2	Increase in blood pressure
Beryllium	0.004	Intestinal lesions
Cadmium	0.005	Kidney damage
Chromium (total)	0.1	Allergic dermatitis
Copper	TT1; Action Level=1.3	Short term exposure: Gastrointestinal distress Long term exposure: Liver or kidney damage People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level
Cyanide (as free cyanide)	0.2	Nerve damage or thyroid problems
Fluoride	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth
Lead	TT[1]; Action Level=0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities Adults: Kidney problems; high blood pressure
Mercury (inorganic)	0.002	Kidney damage
Nitrate (measured as Nitrogen)	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.
Nitrite (measured as Nitrogen)	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.
Selenium	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems
Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems

[1] Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L.

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Radionuclides	MCL	Potential Health Effects
Alpha particles	15 picocuries per Liter (pCi/L)	Increased risk of cancer
Beta particles and photon emitters	4 millirems per year	Increased risk of cancer
Radium 226 and Radium 228 (combined)	5 pCi/L	Increased risk of cancer
Uranium	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity

Disinfectants	MRDL[1]	Potential Health Effects
Chloramines (as Cl_2)	MRDL=4.0	Eye/nose irritation; stomach discomfort, anemia
Chlorine (as Cl_2)	MRDL=4.0	Eye/nose irritation; stomach discomfort
Chlorine dioxide (as ClO_2)	MRDL=0.8	Anemia; infants & young children: nervous system effects

[1]Maximum Residual Disinfectant Level (MRDL) - The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.

Disinfection Byproducts	MCL (mg/L)	Potential Health Effects
Bromate	0.010	Increased risk of cancer
Chlorite	1.0	Anemia; infants & young children: nervous system effects
Haloacetic acids (HAA5)	0.060	Increased risk of cancer
Total Trihalomethanes (TTHMs)	0.080	Liver, kidney or central nervous system problems; increased risk of cancer

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Microorganisms	TT	Potential Health Effects
Cryptosporidium	TT[1]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)
Giardia lamblia	TT[1]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)
Heterotrophic plate count	TT[1]	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.
Legionella	TT[1]	Legionnaire's Disease, a type of pneumonia
Total Coliforms (including fecal coliform and E. Coli)	5.0%[2]	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present[3]
Turbidity	TT[1]	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing microorganisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches.
Viruses (enteric)	TT[1]	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)

[1] EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- Cryptosporidium (as of1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal.
- Giardia lamblia: 99.9% removal/inactivation
- Viruses: 99.99% removal/inactivation
- Legionella: No limit, but EPA believes that if Giardia and viruses are removed/inactivated, Legionella will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units(NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
- HPC: No more than 500 bacterial colonies per milliliter.
- Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005); Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, Cryptosporidium removal requirements, updated watershed control requirements for unfiltered systems).
- Filter Backwash Recycling; The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state.

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[2] more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or E. coli if two consecutive TC-positive samples, and one is also positive for E.coli fecal coliforms, system has an acute MCL violation.

[3] Fecal coliform and E. coli are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

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Organic Chemicals	MCL (mg/L)	Potential Health Effects
Acrylamide	TT[1]	Nervous system or blood problems; increased risk of cancer
Alachlor	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer
Atrazine	0.003	Cardiovascular system or reproductive problems
Benzene	0.005	Anemia; decrease in blood platelets; increased risk of cancer
Benzo(a)pyrene (PAHs)	0.0002	Reproductive difficulties; increased risk of cancer
Carbofuran	0.04	Problems with blood, nervous system, or reproductive system
Carbon tetrachloride	0.005	Liver problems; increased risk of cancer
Chlordane	0.002	Liver or nervous system problems; increased risk of cancer
Chlorobenzene	0.1	Liver or kidney problems
2,4-D	0.07	Kidney, liver, or adrenal gland problems
Dalapon	0.2	Minor kidney changes
1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Reproductive difficulties; increased risk of cancer
o-Dichlorobenzene	0.6	Liver, kidney, or circulatory system problems
p-Dichlorobenzene	0.075	Anemia; liver, kidney or spleen damage; changes in blood
1,2-Dichloroethane	0.005	Increased risk of cancer
1,1-Dichloroethylene	0.007	Liver problems
cis-1,2-Dichloroethylene	0.07	Liver problems
trans-1,2-Dichloroethylene	0.1	Liver problems
Dichloromethane	0.005	Liver problems; increased risk of cancer
1,2-Dichloropropane	0.005	Increased risk of cancer
Di(2-ethylhexyl) adipate	0.4	Weight loss, liver problems, or possible reproductive difficulties.
Di(2-ethylhexyl) phthalate	0.006	Reproductive difficulties; liver problems; increased risk of cancer
Dinoseb	0.007	Reproductive difficulties
Dioxin (2,3,7,8-TCDD)	0.00000003	Reproductive difficulties; increased risk of cancer
Diquat	0.02	Cataracts
Endothall	0.1	Stomach and intestinal problems
Endrin	0.002	Liver problems
Epichlorohydrin	TT[1]	Increased cancer risk, and over a long period of time, stomach problems
Ethylbenzene	0.7	Liver or kidneys problems
Ethylene dibromide	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer
Glyphosate	0.7	Kidney problems; reproductive difficulties

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Organic Chemicals	MCL (mg/L)	Potential Health Effects
Heptachlor	0.0004	Liver damage; increased risk of cancer
Heptachlor epoxide	0.0002	Liver damage; increased risk of cancer
Hexachlorobenzene increased risk of cancer	0.001	Liver or kidney problems; reproductive difficulties;
Hexachlorocyclopentadiene	0.05	Kidney or stomach problems
Lindane	0.0002	Liver or kidney problems
Methoxychlor	0.04	Reproductive difficulties
Oxamyl (Vydate)	0.2	Slight nervous system effects
Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer
Pentachlorophenol	0.001	Liver or kidney problems; increased cancer risk
Picloram	0.5	Liver problems
Simazine	0.004	Problems with blood
Styrene	0.1	Liver, kidney, or circulatory system problems
Tetrachloroethylene	0.005	Liver problems; increased risk of cancer
Toluene	1	Nervous system, kidney, or liver problems
Toxaphene	0.003	Kidney, liver, or thyroid problems; increased risk of cancer
2,4,5-TP (Silvex)	0.05	Liver problems
1,2,4-Trichlorobenzene	0.07	Changes in adrenal glands
1,1,1-Trichloroethane	0.2	Liver, nervous system, or circulatory problems
1,1,2-Trichloroethane	0.005	Liver, kidney, or immune system problems
Trichloroethylene	0.005	Liver problems; increased risk of cancer
Vinyl chloride	0.002	Increased risk of cancer
Xylenes (total)	10	Nervous system damage

[1] Each water system must certify, in writing, to the state (using third-party or manufacturer's certification) that when acrylamide and epichlorohydrin are used in drinking water systems, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows:

- Acrylamide = 0.05% dosed at 1 mg/L (or equivalent)
- Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent)

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Contaminant	Secondary Standard
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	Noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

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Retention Tank Design

A retention tank differs from a contact tank in that a retention tank must have a large enough diameter to slow down the flow of the water and allow any precipitated materials to settle out and be retained in the tank. In addition, a retention tank must have an inlet distributor specifically designed for non-turbulent flow of water. A retention tank is not required if the expected level of suspended solids is less than 20 mg/L, since a depth filter can handle any carry-over of precipitated material from a contact tank. The most common application requiring a retention tank is alum feed for coagulation.

Before a tank can be sized, two factors must be known: (1) maximum service flow rate and (2) desired retention time. The maximum service flow rate must be determined by a fixture count. In most residential applications, the service flow rate is about 6-7 gpm. However, a whirlpool tub typically fills at 12-15 gpm, so that is one fixture to note. For retention of suspended solids, the retention time should be 20 minutes.

1. Based on the maximum service flow, select from Table 1 the minimum retention diameter required. This table is based on a flow rate of approximately 1 gpm per square foot of tank area.
2. Determine the minimum retention gallons required by multiplying the maximum service flow rate by the desired retention time. Example: The maximum service flow rate is 6 gpm and the desired retention time is 20 minutes. 6 gpm x 20 minutes = 120 gallons minimum retention gallons.
3. Based on the minimum retention tank diameter (Step 1) and the minimum retention gallons (Step 2), select from Table 2 the minimum distance (height) between the inlet and outlet, the reaction zone. Refer to Figure 1.

TABLE 1- MINIMUM TANK DIAMETER

Service Flow Maximum (gpm)	Minimum Tank Diameter (Inches)
2	20
4	28
6	36
8	36
10	42
12	48
14	50
16	56
18	56
20	60

NOTE: *If the table does not contain values for the diameter or gallons you require, calculate on the basis of multiple tanks in parallel, remembering that the flow through each tank will equal the total flow divided by the number of tanks.*

4. A quiet zone for settling of precipitate should be provided equal to about 25% of the reaction zone. Multiply the reaction zone height (h, Step 3) by 1.25. This equals the minimum working height, w.

   $$h \times 1.25 = w$$

   Working height (w) minus reaction zone height (h) gives the approximate settling zone depth (S), as shown in Figure 1.

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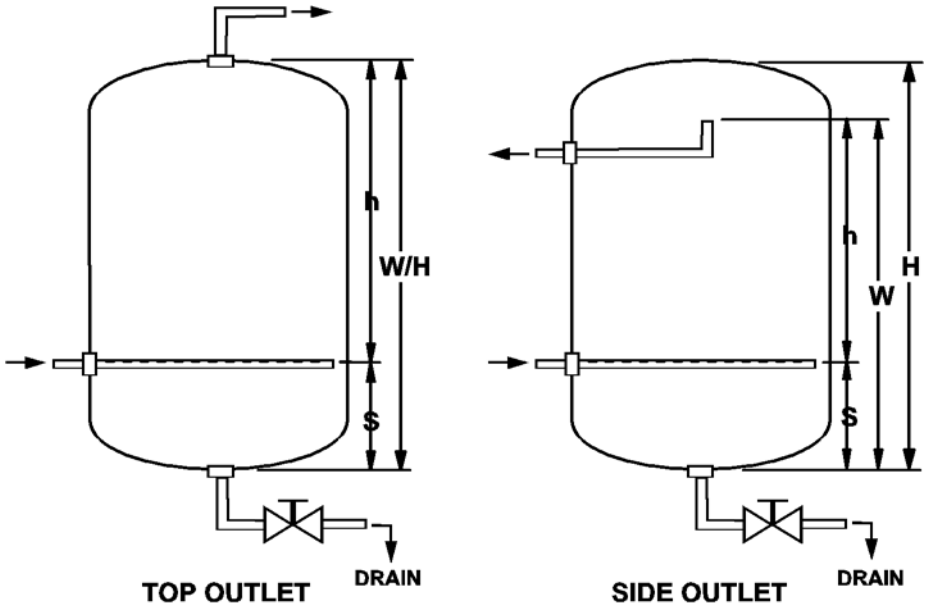
Tank Openings

TABLE — 2 MINIMUM REACTION ZONE HEIGHT * (Inches)

Tank Diameter (Inches)	RETENTION GALLONAGE																	
	20	40	60	80	100	120	150	200	250	300	350	400	450	500	600	700	800	900
20	15	30																
28	8	16	23	30	38													
36		10	14	20	23	28												
42			10	14	17	20	25											
48				10	13	16	19	26	32	38	45							
50					12	14	18	24	30	35	42	48	53	60				
56						12	14	19	24	28	33	38	42	48	56	66		
60							13	17	21	26	29	34	37	42	52	58	68	74

Figure 1



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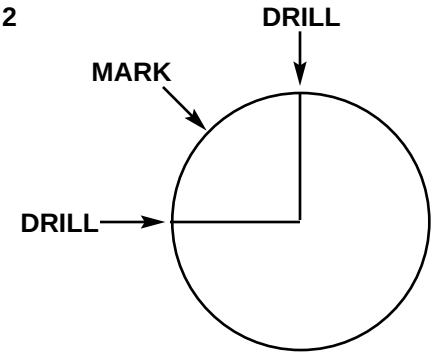
Openings will be required for inlet, outlet, and blow-down connections. Their size and type will depend largely upon the size and materials of interconnecting pipe and tank construction. Ideally, the outlet should be at the top of the tank, either on the head or the sideshell, and the blow-down on the bottom head to ensure complete expulsion of sediment. The inlet will be positioned at the junction of the reaction and settling zones.

Inlet Manifold

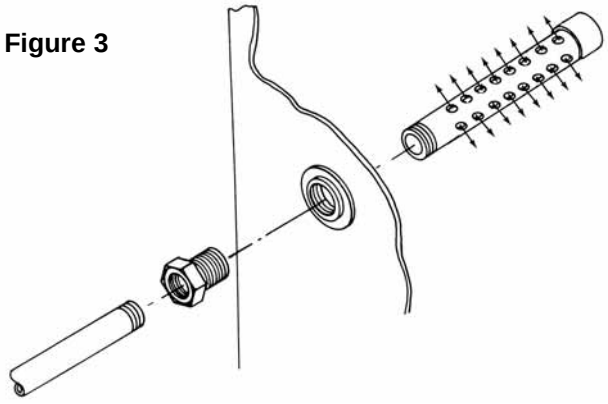
Figure 2



Proper distribution of water into the tank is important. Horizontal distribution allows precipitated mater to settle along the sides of the tank and keeps the settling zone from being agitated. The manifold should extend across the entire inner diameter of the tank. Drill two rows of holes at a 90° angle in the pipe along its entire length (Fig. 2) and cap the end.

Connect the manifold to a suitable fitting for installation into the tank opening. Figure 3 shows one possible method utilizing a bushing that has been tapped at both ends. Connect the manifold to the bushing, then mark the bushing to indicate the position of the holes in the manifold, as indicated in Figure 2. Install the assembly into the tank with the mark at the top, so the holes will direct the water out and up at a 45° angle.

Figure 3



Blow Down

Accumulated sediment must be rinsed from the tank on a regular basis by a process called "blow down", which may be done either manually or automatically. The blow down line should be located at the lowest possible point in the tank to ensure complete rinsing of the sediment (Fig. 1).

For manual blow down, any hand valve of suitable materials, size, and construction will do. When blowing down, the valve should be left open until the water to drain is clear, or at least equal in appearance to the incoming water.

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Automatic blow down will require a Normally Closed solenoid valve sized equal to or larger than the incoming water line. The valve should have a self-cleaning design so that it will not be stuck open by sediment from the tank. An electronic cycling timer, which can be obtained from an electrical supply store, should be used to activate the solenoid.

Whichever method is used, a flow control should be used in the blow down line so that the flow to drain does not exceed the service flow rate design for the tank.

Multiple Tank Systems

To ensure uniform distribution of flow through multiple tank systems, the piping from the common inlet to the common outlet of each tank, and from each tank to the common outlet must be of equal length. Figure 4 illustrates correct and incorrect piping arrangements for duplex tank systems, and Figure 5 illustrates the same for triplex (or more) tank systems.

Figure 4

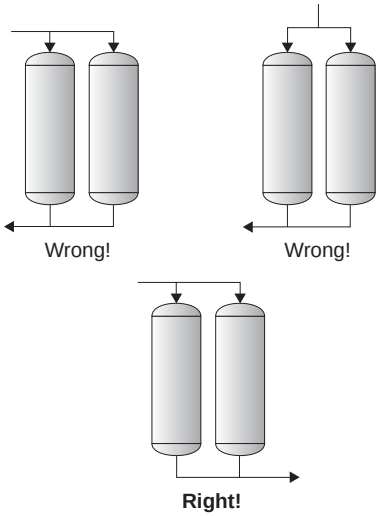
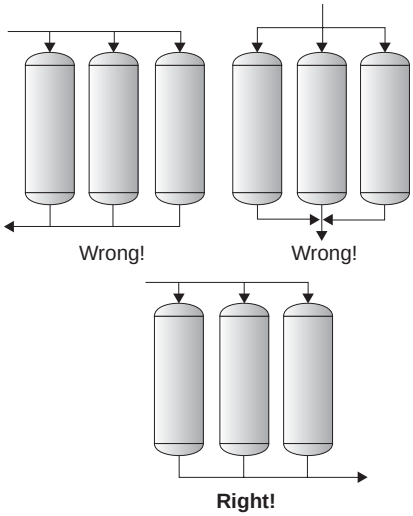


Figure 5



The inlet manifolds for each tank must be identical, with the same size and number of holes. Differences in piping length and manifold construction can result in one tank receiving more flow than the others, possibly resulting in particulate carry-over.

Sampling

At a minimum, sample cocks should be provided at the outlet of each retention tank to measure chemical residual, pH, and any other applicable water chemistry characteristics. Systems using potassium permanganate must have a sample cock at the inlet to each retention tank to ensure proper dosage (the water entering the tank should be slightly pink).

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Well Pump Flow Rate

Using a watch and a 5-gallon bucket, measure the well pump flow rate as follows:

1. Locate a faucet near the pump pressure switch or the pump itself.
2. Turn on the water. When the pump starts, start timing how long it runs until it shuts off. Immediately shut off the water when the pump shuts off, then record the pump run time in seconds. Example: 22 seconds.
3. Turn on the water and start filling the bucket until the pump starts again. If the bucket becomes full before the pump starts, dump the water and continue filling. Record the total volume in gallons. Example: 3.7 gallons
4. Divide the volume of gallons by the pump run time. This gives the flow rate in gallons per second. Example: 3.7 gallons/22 seconds = 0.168 gallons per second.
5. Multiply the result of Step 4 by 60 to get gallons per minute. Example: 0.168 gallons per second times 60 = 10.1 gpm.

Conversion Factors

Refer to Chapter 4, Testing, for using the information in the table to convert between concentration as the substance to concentration as calcium carbonate ($CaCO_3$).

Substance	Formula	Molecular Weight	Equivalent Weight	Substance to $CaCO_3$ Equivalent	$CaCO_3$ Equivalent to Substance
Calcium	Ca^{+2}	40.1	20.0	2.50	0.40
Magnesium	Mg^{+2}	24.3	12.2	4.12	0.24
Sodium	Na^{+}	23.0	23.0	2.17	0.46
Potassium	K^{+}	39.1	39.1	1.28	0.78
Strontium	Sr^{+2}	87.6	43.8	1.14	0.88
Barium	Ba^{+2}	137.4	68.7	0.73	1.37
Iron, ferrous	Fe^{+2}	55.8	27.9	1.79	0.56
Iron, ferric	Fe^{+3}	55.8	18.6	2.69	0.37
Manganese	Mn^{+2}	54.9	27.5	1.82	0.55
Copper	Cu^{+2}	63.6	31.8	1.57	0.64
Zinc	Zn^{+2}	65.4	32.7	1.54	0.65
Aluminum	Al^{+3}	27.0	9.0	5.56	0.18
Chloride	Cl^{-}	35.5	35.5	1.41	0.71
Nitrate	NO_3^{-}	62.0	62.0	0.81	1.24
Nitrite	NO_2^{-}	46.0	46.0	1.09	0.94
Sulfate	SO_4^{-2}	96.1	48.0	1.04	0.96
Bicarbonate	HCO_3^{-}	61.0	61.0	0.82	1.22
Carbonate	CO_3^{-2}	60.0	30.0	1.67	0.60
Fluoride	F^{-}	19.0	19.0	2.66	0.38
Silica	SiO_2	60.1	60.1	0.83	1.20

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Ironeater™ Chemical Feed System

As noted in the section on Softeners in Chapter 5, a Sofner-Gard™ accessory is available to allow a softener to remove clear water iron without fouling the resin. An alternative system is needed if the softener contains more than 1.5 cubic feet of resin or the softener control is not compatible with the Sofner-Gard accessory.

The Ironeater chemical feeder system consists of a small chemical feeder and a small-diameter solution tank. With some softener controls, a signal switch kit, Cat. No. 00-4477-83, also is needed.

Chemical Feeder Sizing

The system is intended to deliver 1 dry ounce of Ironeater chemical for every cubic foot of resin. Since the chemical is dissolved in water at three pounds per gallon, the feeder must deliver 0.02 gallons (2.67 liquid ounces) of solution per cubic foot of resin during, or just prior to, regeneration.

Calculate the required feed rate as follows:

1. Determine the volume of resin in cubic feet. Example: A PV-90 softener contains 3 cubic feet of resin.
2. Multiply the resin volume by 30. Example: 3 cubic feet x 30 = 90
3. Divide the result of Step 2 by the amount of time the chemical feeder will be activated.
   NOTE: *The activation time will vary depending on the type of softener control and timer (see below). Example: 90/94 minutes = 0.96 gpd.*

Be sure to choose a chemical feeder than can feed accurately at the calculated feed rate.

Solution Tank Sizing

The Ironeater chemical solution has a "shelf life" of 60 days. To determine how much chemical will be used during this time:

1. Multiply the feed rate (gpd) times the number of minutes the feeder will be activated, then divide by 1440. Example: 0.96 gpd x 94 minutes = 90.24, then 90.24/1440 = 0.063 gallons per regeneration.
2. Estimate the number of times the softener will regenerate in a 60 day period. Example: Once every 3 days, or 20 regenerations in 60 days.
3. Multiply the gallons per regeneration times the number of regenerations in 60 days. Example: 0.063 gallons x 20 = 1.26 gallons in a 60 day period.

In most applications, a standard solution tank will be too large. A small diameter tank is recommended since any solution remaining after 60 days must be discarded before making fresh solution. As the table shows, the larger the tank diameter, the larger the volume of solution per inch of solution depth. There must be a minimum solution depth allowed so that the suction fitting does not draw air.

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Appendices

Container ID, in.	Gallons per inch
4	0.053
6	0.122
8	0.217
10	0.339
12	0.488
14	0.664
16	0.867
18	1.10

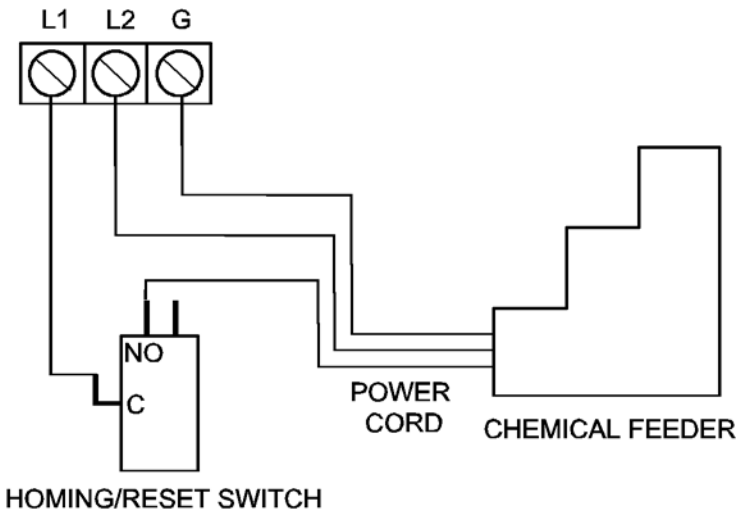
Chemical Feeder Hydraulic Installation

Install the suction fitting into the solution container and secure the tubing in place. Drop the injection fitting into the brine valve chamber in the brine tank until it is level with the bottom of the brine valve. Secure the tubing to the brine valve with plastic ties to prevent the tubing from interfering with the brine valve float.

Chemical Feeder Electrical Installation

Electrical connections will depend on the type of timer and control valve. All wiring must conform to required electrical codes.

Culligan 115VAC mechanical timers. Cut the plug from the feeder power cord. Strip off the insulation to expose the black (HOT, L1), white (NEUTRAL, L2), and green (Ground, G) wires. Locate the timer homing switch on the back of the timer. The NO terminal on this switch is HOT when the timer is not in service. Connect a wire from this terminal to the black (HOT, L1) wire on the power cord. Connect the white power cord wire to the NEUTRAL terminal in the control, and green power cord wire to the ground terminal. When connected in this manner, the chemical feeder activation time is 120 minutes.



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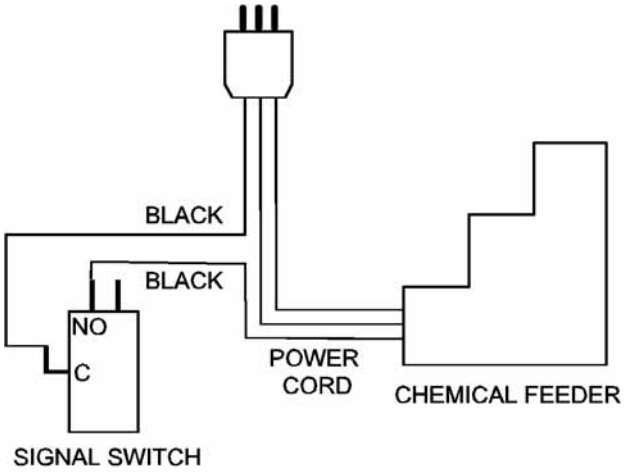
Soft-Minder Twin 115VAC mechanical timers. Cut the plug from the feeder power cord. Strip off the insulation to expose the black (HOT, L1), white (NEUTRAL, L2), and green (Ground, G) wires. Locate the program reset switch (with the half-moon curve on the lever) on the timer. The NO terminal on this switch is HOT when the pin wheel is not in service. Connect a wire from this terminal to the black (HOT, L1) wire on the power cord. Connect the white power cord wire to the NEUTRAL terminal in the control, and green power cord wire to the ground terminal. When connected in this manner, the chemical feeder activation time is the same as the total time shown on the pin wheel (typically 180 minutes).

Electronic timers with Culligan power valves. These controls can use the signal switch kit (Cat. No. 00-4477-83), which consists of a cam, switch, and switch bracket. The cam is mounted on the control's motor cam, and activates the switch when the piston is not in the service position. The black power cord wire can be cut and the ends connected to the common (C) and normally open (NO) terminals of the signal switch, as shown in the drawing.



Alternative chemical feeder

The Stenner 25BDF5 chemical feeder is not activated by an external signal. Rather, it is set to feed from 1 to 21 ounces of chemical, from 1 to 24 times per day. Because it does not require wiring to the softener control, it can be used with any softener. However, because it must activate at least once per day, it may cause excessive chemical usage.

The hydraulic installation is the same as for other chemical feeders.

The table below shows the feeder dosage setting, in liquid ounces, for the amount of resin in the media tank and the regeneration frequency. The chemical usage in a 60-day period is 60 times the feeder dosage setting, divided by 128 to convert from ounces to gallons. Example: A softener with 5 cubic feet of resin and regenerating every 3rd day would have a feeder dosage of 7 ounces. 60 x 7 = 420 ounces, or 3.3 gallons used in a 60-day period. Use the table for solution tank sizing to determine the proper diameter tank. In this example, a 6-inch diameter tank would have a solution depth of 3.3/0.122 = 27 inches.

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Appendices

Liquid Ounces of Chemical Required

Resin, cu.ft.	Daily Regeneration	Less Than Daily Regeneration
0.86	3	2
1	3	2
1.4	4	2
2	6	3
3	8	4
4	11	6
5	14	7
6	16	8
7	19	10
8	21	11
10	NA	14
15	NA	20

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This page contains materials and DCO information. IT DOES NOT PRINT AS PART OF THE DOCUMENT!

Materials & Description: Problem Water Manual PN 01016428

Size: **8.5” x 11”**

Color: **Black Ink, 2 sided : Tabs single sided**

Stock: **Front (2 sided) & Back (Blank) Covers on 110# White Index**

Inside on 20# white

Other: **1/6-Cut Tabs**

Collate

Shrink Wrap

3 Hole Drill

LET	CHANGE	BY	APRVD	DCO	DATE
A	NEW ART CREATED	PH/LR	BH	5525	12/08/04